PB90-194705

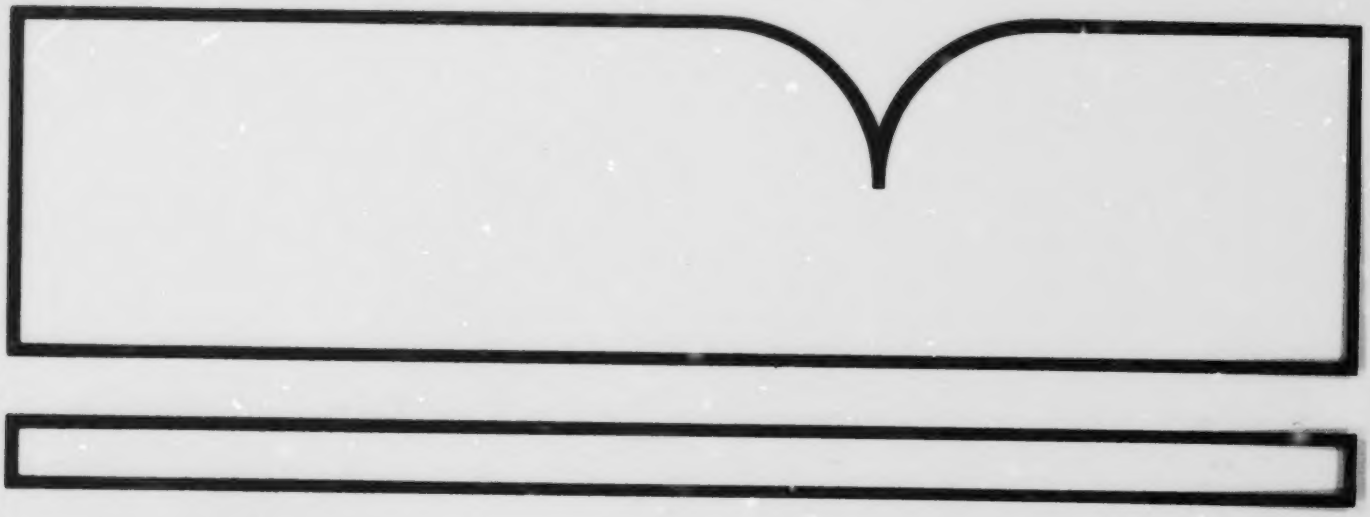
Treatability of RCRA Compounds in a BOD/Nitrification Wastewater Treatment System with Dual Media Filtration

Cincinnati Univ., OH

Prepared for:

Environmental Protection Agency, Cincinnati, OH

Apr 90



U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/2-90/013		PB90 194705/AS

4. TITLE AND SUBTITLE	5. REPORT DATE
Treatability of RCRA Compounds in a BOD/Nitrification Wastewater Treatment System with Dual Media Filtration	April, 1990
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Steven I. Safferman and Sanjoy K. Bhattacharya	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
University of Cincinnati Cincinnati, Ohio 45221	11. CONTRACT/GRANT NO. 68-03-4038
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Risk Reduction Engineering Laboratory-Cincinnati, Ohio Office of Research and Development U. S. Environmental Protection Agency Cincinnati, Ohio 45268	Complete 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

TPM - Sidney A. Hannah (513/684-2621 - FTS and Commercial)

16. ABSTRACT

This study investigates the treatability and fate of 28 organic RCRA compounds in a combined organic removal and nitrification process and by secondary effluent gravity filtration. A 3.8 L/min pilot-scale extended aeration wastewater treatment system with dual media effluent filter was utilized for the study. At a total concentration of approximately 1.5 mg/L organics (sum of the concentration of all 28 RCRA compounds) into the aeration basin, most of the compounds were removed to below detectable limits by secondary treatment under either acclimated or unacclimated conditions. The effectiveness of the effluent filter in removing organic compounds could not be assessed as most of the compounds entering the filter were already reduced to below detectable levels. Ammonia removal was significantly impaired at a total concentration of 19.2 mg/L organics into the aeration basin. COD reduction was apparently not inhibited at any of the spike concentrations tested.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	92
	20. SECURITY CLASS (This page)	22. PRICE
	UNCLASSIFIED	A05

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

PB90-194705

EPA/600/2-90/013
April,1990

TREATABILITY OF RCRA COMPOUNDS IN A BOD/NITRIFICATION WASTEWATER TREATMENT SYSTEM WITH DUAL MEDIA FILTRATION

by

Steven I. Safferman
Sanjoy K. Bhattacharya
University of Cincinnati
Department of Civil and Environmental Engineering
Cincinnati, Ohio 45221

Contract No. 68-03-4038

Project Officer

Sidney A. Hannah
Water and Hazardous Waste Treatment Research Division
Risk Reduction Engineering Laboratory
Cincinnati, Ohio 45268

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

DISCLAIMER

This material has been funded wholly or in part by the United States Environmental Protection Agency under contract No. 68-03-4038 to the University of Cincinnati. It has been subject to the Agency's review and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities.

This publication is one of the products of that research and is a vital communication link between the researcher and the user community. The study described provides an understanding of the fate and treatability of organic RCRA compounds in a BOD/Nitrification wastewater treatment system with dual media effluent filtration. The trends found from the research form the foundation for future studies and the development of equitable policies for the discharge of such compounds to and from a wastewater treatment facility.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

The discharge of nitrogen and potentially toxic or hazardous organic compounds to the environment from wastewater treatment plants has come under scrutiny in recent years. Of specific concern is the exclusion of many organic compounds from RCRA regulations if they are discharged into a wastewater treatment plant. This study investigates the treatability and fate of 28 organic RCRA compounds in a combined organic removal and nitrification process and by secondary effluent gravity filtration. A 3.8 L/min pilot-scale extended aeration wastewater treatment system with dual media effluent filter was utilized for the study. At a total concentration of approximately 1.5 mg/L organics (sum of the concentration of all 28 RCRA compounds) into the aeration basin, most of the compounds were removed to below detectable limits by secondary treatment under either acclimated or unacclimated conditions. The effectiveness of the effluent filter in removing organic compounds could not be assessed as most of the compounds entering the filter were already reduced to below detectable levels. Ammonia removal was significantly impaired at a total concentration of 19.2 mg/L organics into the aeration basin. COD reduction was apparently not inhibited at any of the spike concentrations tested.

This report was submitted in fulfillment of Contract No. 68-03-4038 by the University of Cincinnati under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from September, 1987 to March, 1988, and work was completed as of June, 1989.

CONTENTS

		PAGE
FOREWORD		iii
ABSTRACT		iv
FIGURES		ix
TABLES		x
SECTION 1	INTRODUCTION	
1.1	BACKGROUND	1
1.2	RCRA ACT	1
1.3	RESEARCH OBJECTIVES	3
SECTION 2	CONCLUSIONS AND RECOMMENDATIONS	4
SECTION 3	LITERATURE REVIEW	
3.1	REMOVAL OF RCRA COMPOUNDS BY ACTIVATED SLUDGE	5
3.1.1	Volatilization of Organic Compounds	5
3.1.2	Adsorption of Compounds on Sludge	6
3.1.3	Biodegradation of Organic Compounds	7
3.1.4	Overall Removal of Organic Compounds	8
3.1.5	Unacclimated Conditions	8

3.2 REMOVAL OF RCRA COMPOUNDS BY EFFLUENT FILTRATION 9

3.3 INHIBITORY ORGANIC RCRA COMPOUND CONCENTRATIONS 9

3.4 NITROGEN TRANSFORMATIONS..... 9

3.4.1 Biological Transformation of Nitrogen 10

3.4.2 Nitrification 12

3.4.3 Design of Biological Nitrification Systems 13

3.4.4 Other Nitrogen Removal Processes ... 14

3.5 THE IMPORTANCE OF A SYSTEM'S SRT FOR THE REMOVAL OF ORGANIC COMPOUNDS 14

3.6 INHIBITION OF THE NITRIFICATION PROCESS CAUSED BY ORGANIC RCRA COMPOUNDS 15

SECTION 4 EXPERIMENTAL DESIGN

4.1 SYSTEM DESIGN AND OPERATIONS 16

4.2 RCRA COMPOUND SPIKING SYSTEM 19

4.3 PHASES OF THE STUDY 19

4.3.1 Process Interference caused by Organic RCRA Compounds (Phase 1) 23

4.3.2 Fate and Treatability of Organic RCRA Compounds (Phase 2)... 23

4.3.3 The Removal of Organic RCRA Compounds by Dual Media Effluent Filtration (Phase 3) 25

SECTION 5 ANALYTICAL PROCEDURES

5.1 CONTROL VARIABLES 26

5.2 PROCESS PARAMETERS 27

5.3 TOXICS ANALYSES 28

SECTION 6 RESULTS

6.1 INTERFERENCE CAUSED BY ORGANIC RCRA 30
COMPOUNDS IN AN ACCLIMATED NITRIFICATION PROCESS

6.1.1 Effect of Organic RCRA 30
Compounds on Control and Operating Variables

6.1.2 Effect of RCRA Compounds on Process 34
Control Parameters

6.1.3 Comparison of Process Parameters .. 34
Between the Baseline, Control and Spiked Operating Conditions

6.1.4 Conclusion 47

6.2 INTERFERENCE CAUSED BY ORGANIC 47
RCRA COMPOUNDS IN AN UNACCLIMATED NITRIFICATION PROCESS

6.2.1 Control and Operating Variables 47
for the Unacclimated System

6.2.2 Interference caused by Shock 50
Loading of Organic RCRA Compounds

6.3 REMOVAL OF ORGANIC RCRA COMPOUNDS BY AN ... 50
ACCLIMATED EXTENDED AERATION WASTEWATER TREATMENT SYSTEM

6.4 REMOVAL OF ORGANIC RCRA COMPOUNDS BY AN UNACCLIMATED EXTENDED AERATION WASTEWATER TREATMENT SYSTEM ... 60

6.5 REMOVAL OF ORGANIC RCRA COMPOUNDS BY DUAL MEDIA EFFLUENT FILTRATION 60

6.6 QUALITY CONTROL 73

SECTION 7 REFERENCES 76

FIGURES

NUMBER		PAGE
3.1	THE NITROGEN CYCLE	11
4.1	SCHEMATIC OF NITRIFICATION SYSTEM	17
4.2	DUAL MEDIA EFFLUENT FILTER	18
6.1	ACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT COD	35
6.2	ACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT AMMONIA	36
6.3	ACCLIMATED CONDITIONS, INFLUENT, EFFLUENT AND MIXED LIQUOR NITRATE	37
6.4	ACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT BOD	38
6.5	ACCLIMATED CONDITIONS, AMMONIA, TKN, NITRATE VS. CONCENTRATION OF SPIKE ...	44
6.6	UNACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT COD	51
6.7	UNACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT AMMONIA	52
6.8	UNACCLIMATED CONDITIONS, EFFLUENT, INFLUENT AND MIXED LIQUOR NITRATE	53
6.9	UNACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT BOD	54

TABLES

NUMBER		PAGE
4.1	DESIGN PARAMETERS	20
4.2	TESTED COMPOUNDS AND PROPERTIES	21
6.1	pH AND ALKALINITY FOR ACCLIMATED CONDITIONS	31
6.2	TOTAL SUSPENDED SOLIDS FOR ACCLIMATED CONDITIONS	32
6.3	CONTROL VARIABLES FOR ACCLIMATED CONDITIONS	33
6.4	COD FOR ACCLIMATED CONDITIONS	39
6.5	AMMONIA FOR ACCLIMATED CONDITIONS	40
6.6	PREDICTED AMMONIA REDUCTION FOR ACCLIMATED CONDITIONS	41
6.7	NITRATE FOR ACCLIMATED CONDITIONS	42
6.8	TKN FOR ACCLIMATED CONDITIONS	43
6.9	TOTAL PHOSPHORUS FOR ACCLIMATED CONDITIONS	45
6.10	PROCESS PARAMETERS FOR UNACCLIMATED CONDITIONS, DAY 1 TO 38	46
6.11	OPERATING VARIABLES FOR UNACCLIMATED CONDITIONS	48
6.12	CONTROL VARIABLES FOR UNACCLIMATED CONDITIONS	49

6.13 PROCESS PARAMETERS FOR UNACCLIMATED CONDITIONS FOR DAY 1 TO 63 55

6.14 SAMPLING EVENT 1 FOR ACCLIMATED CONDITIONS 56

6.15 SAMPLING EVENT 2 FOR ACCLIMATED CONDITIONS 57

6.16 SAMPLING EVENT 3 FOR ACCLIMATED CONDITIONS 58

6.17 SUMMARY OF SAMPLING EVENTS FOR ACCLIMATED CONDITIONS 59

6.18 SAMPLING EVENT 1 FOR UNACCLIMATED CONDITIONS 61

6.19 SAMPLING EVENT 2 FOR UNACCLIMATED CONDITIONS 62

6.20 SAMPLING EVENT 3 FOR UNACCLIMATED CONDITIONS 63

6.21 SUMMARY OF SAMPLING EVENTS FOR UNACCLIMATED CONDITIONS 64

6.22 TSS AND COD FOR EFFLUENT FILTERS FOR ACCLIMATED CONDITIONS 65

6.23 TOXIC FILTERS SAMPLING EVENTS FOR ACCLIMATED CONDITIONS 66

6.24 SUMMARY OF TOXIC SAMPLING EVENTS FOR ACCLIMATED CONDITIONS 72

6.25 QUALITY CONTROL 75

SECTION 1
INTRODUCTION

1.1 BACKGROUND

The effects of discharging hazardous wastes into the environment without adequate treatment have become of increased concern to regulatory agencies and the scientific community. Some of the compounds associated with hazardous waste can accumulate in the environment and are mutagenic, teratogenic or carcinogenic (Petrasek, 1983). They can also volatilize into the atmosphere, cause ground water contamination and inhibit wastewater treatment processes.

In 1985 it was estimated that 164.1 million tons of hazardous waste, out of the 213.2 million tons generated, were discharged to publicly owned wastewater treatment works (POTW). Only 11% of this waste received pretreatment (CMA, 1987). Consequently the treatability of wastes that have the potential to be toxic or hazardous must be assessed and their effect on existing treatment facilities understood. The need for increased understanding of the treatability of this waste is further realized as more stringent regulations on the discharge of hazardous chemicals into the environment are forthcoming. Such changes include rewriting many regulations to limit the quantity of hazardous chemicals discharged into the environment instead of stating that they shall be treated with the best available technology (Bowers, 1988), and more stringent organic chemical, plastics and synthetic fiber (OCPSF) regulations (Newton, 1980).

Another recent change in the wastewater treatment industry has been the requirement to stabilize nitrogen in sewage. Excess nitrogen can result in an oxygen demand and cause biostimulation in the receiving stream. One common means of achieving both nitrification and BOD removal is with an extended aeration wastewater treatment plant.

To investigate the effect of hazardous chemicals on a nitrification system and their removal by the system and secondary effluent filtration, 28 Resource Conservation and Recovery Act (RCRA) organic compounds were spiked into a pilot-scale extended aeration wastewater treatment (nitrification) system under both acclimated and unacclimated conditions.

1.2 RCRA ACT

The RCRA Act of 1976 amended the Solid Waste Disposal Act (SWDA) which was designed to regulate wastes. Amendments to the RCRA act were passed in 1978, 1980 and 1984. Its aims are to (U.S. EPA, 1986):

-promote human health and the environment,
-conserve energy and natural resources and
-reduce or eliminate hazardous wastes
as quickly as possible.

The three subtitles of the RCRA act that explain its approach to handling wastes are:

Subtitle C: Hazardous Waste Management
Subtitle D: Solid Waste Plans
Subtitle I: Underground Storage Tank Program

The other subtitles of the act deal with the administration of the act, responsibilities, research and development and other miscellaneous provisions.

RCRA regulates wastes that are not covered by either the Clean Air Act or the Clean Water Act. Also, RCRA is designed to handle only existing and future hazardous waste and not past problems. The Comprehensive Environmental Response, Compensation and Liability Act, 1980, (Superfund), and its amendments handles that aspect of hazardous waste (Quarles, 1982).

Subtitle C, "Hazardous Waste Management," has received the most attention because of its "cradle to grave" approach to managing hazardous waste. This approach holds the generator (hazardous waste producer) responsible for the waste from the time it is produced to the time of its ultimate disposal. Therefore, responsibilities include classifying the waste, finding approved transportation, selecting an approved treatment or storage facility and producing precise documentation of each step.

Hazardous waste, as defined by RCRA in Section 3001, is solid waste that exhibits toxic or hazardous characteristics (U.S. EPA, Para. 5, 1976). Solid waste is any solid, liquid, semi-liquid or contained gaseous material which is discarded, or has served its intended purpose as a by-product of an industrial or manufacturing plant (U.S. EPA, Para. 7, 1976). A hazardous material has one or more of the following properties: ignitability, reactivity, corrosivity or toxicity (Quarles, 1982). To classify a material as hazardous waste, the above tests can be conducted in accordance with the RCRA act, or the substance can be matched against a list of over 380 compounds the USEPA has classified as hazardous waste (Quarles, 1982). If any of the listed compounds are mixed with other substances, the mixture would still be considered hazardous, unless it is delisted by the USEPA or it does not have the properties of a hazardous waste as defined by RCRA.

A formalized process for generators to challenge chemicals that are regulated under RCRA is available The procedure involves showing that the data that led to the listing of a particular compound are not valid or the particular circumstances or the use of the listed compound are different

(Quarles, 1982). Other RCRA compounds under certain circumstances and for certain industries are also exempt from RCRA regulations.

1.3 RESEARCH OBJECTIVES

As indicated above, certain RCRA compounds are exempt from RCRA regulations. One such exemption is the domestic sewage exclusion. If RCRA compounds, that are not regulated by the Clean Water Act, are discharged into a POTW, they do not require pretreatment. Such compounds are assumed to be treated adequately by the POTW and to cause no process interference or are regulated under the Clean Water Act's National Pretreatment Program.

In order to investigate the effect of potentially hazardous chemicals that fall under the domestic sewage exclusion statement on a wastewater treatment system, twenty-eight RCRA compounds with a broad range of properties were spiked into a pilot-scale nitrification system with dual media secondary effluent filters.

The specific goals of this study were to:

- investigate the treatability and fate of the selected RCRA toxics in the nitrification process for both acclimated and unacclimated conditions and

- determine the effectiveness of effluent dual media filtration for the removal of the composite RCRA toxics.

SECTION 2
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This study investigated the treatability and fate of 28 organic RCRA compounds in a combined organic removal and nitrification process and filtration process. A 3.8 L/min pilot-scale extended aeration wastewater treatment system with a dual media filter was utilized for the study.

The significant conclusions concerning the treatability and fate of the tested RCRA compounds in this study include the following:

- COD removal was not inhibited at the tested composite spike concentrations of 1.8, 4.8 (measured by summing the concentrations of all 28 compounds into the aeration basin), and 19.2 mg/L (estimated based on pump setting).

- Significant inhibition of ammonia removal occurred at the composite spike concentration of 19.2 mg/L (the sum of the concentrations of all 28 compounds into the aeration basin).

- Almost 100% removal of the spiked organic RCRA compounds resulted when the spike concentration was at 1.8 mg/L (the sum of the concentrations of all 28 compounds into the aeration basin) for the acclimated condition and 1.3 mg/L for the unacclimated condition.

- Adsorption did not appear to be a principal mechanism for the removal of the RCRA compounds.

RECOMMENDATIONS

This study indicates that an extended aeration wastewater treatment plant can effectively remove low concentrations of organic RCRA compounds without interfering with BOD, ammonia, and suspended solids removal. However, the many different combinations and concentrations of RCRA compounds that could be expected in the influent to a municipal wastewater treatment plant makes a correlation between this study and a real life situation risky. Further studies and surveys of actual extended aeration wastewater treatment plants would be required to confirm the trends found from this study, determine if or when harmful by-products are produced and find the compound's removal mechanism.

SECTION 3
LITERATURE REVIEW

3.1 REMOVAL OF RCRA COMPOUNDS BY ACTIVATED SLUDGE

The removal of organic RCRA compounds in an activated sludge system primarily results from biodegradation, volatilization, partitioning to the activated sludge or a combination of all three. Other removal mechanisms are hydrolysis, photo-oxidation (U.S. EPA, 1986) and chemical transformations. The three main mechanisms compete with one another, with the predominate one depending on the physical and chemical characteristics of the compounds and the physical and biological conditions at the treatment facility. Each primary removal mechanism is explained below.

3.1.1 Volatilization of Organic Compounds

Many organic compounds are highly volatile and can be partially removed from the liquid stream to the atmosphere. Volatilization can occur from any open surface leading to or within a wastewater treatment plant. However, most volatilization would occur in the aeration basin.

The volatility of a chemical in the gas, liquid or solid phase in water can be predicted from Henry's Law if the chemical's concentration is low (Thibodeaux, 1979). The law states that the concentration of a compound in a liquid is related to the concentration of that compound in the gas above the liquid by a constant (Henry's Law Constant) under standard conditions (U.S. EPA, 1986):

$$H = P/V = P(MW/S)$$

where:

H = Henry's Constant, atm-m^3/mole
MW = molecular weight, grams/mole
P = compound's vapor pressure in air, atm
S = concentration of compound in aeration basin, gram/m^3
V = compound's solubility in water, mole/m^3

Consequently, the higher the Henry's constant the more likely the substance will volatilize.

To predict the actual rate of volatilization from the aeration basin of a wastewater treatment plant, the following formula can be used (Namkung et al., 1987):

$$R_{vol} = -G\ (P_{ex} - P_{in})(MW/RT)$$

where:

R_{vol} = rate of volatilization to gas phase, gram/day
G = air flow rate into aeration basin, m^3/day
P_{ex} = exit partial pressure of compound, atm
P_{in} = inlet partial pressure of compound, atm
R = universal gas constant, $8.206X10^{-5}$ m^3 atm/^oK mole
T = absolute temperature, ^oK

The inlet partial pressure can be assumed to be zero and the exit partial pressure can be found using Henry's Law:

$$P_{ex} = HS/MW$$

Therefore, the rate of removal for a particular compound by volatilization can be predicted by the following equation:

$$R_{vol} = -GHS/RT$$

Volatilization has been found to be a competing mechanism if Henry's constant is greater than 10^{-4} atm m^3/mole (Namkung, et al., 1987) and the compound is not readily biodegraded or adsorbed onto the activated sludge. In general, halogenated hydrocarbons such as 1,2-dichloroethane and 1,1,1 trichloroethane can be easily stripped because of their relatively high Henry's constants. One exception is methylene chloride.

3.1.2 Adsorption of Compounds on Sludge

Organic compounds can adsorb onto organic solids and be removed with the wasted excess sludge. This process has been found to be negligible for volatile organic compound removal (Namkung et al., 1987; U.S. EPA, 1986).

Factors that affect the rate of adsorption include (U.S. EPA, 1986):

-octanol/water partition coefficient (K_{ow}),
-oil and grease concentration,
-electrolytes,
-surface area of sorbent,
-hydrophobicity and
-the presence of other compounds.

K_{ow} is a measure of the compound's tendency to concentrate in the organic phase or the liquid phase. Compounds with log K_{ow} greater than 3.5 are hydrophobic and adsorptive, while ones with log K_{ow} lower than 3.5 are hydrophilic and less likely to be adsorptive (U.S. EPA, 1986). Compounds with high K_{ow} include

bis(2-ethylhexyl) phthalate, butyl benzyl phthalate and 1,4-dichlorobenzene. Other compounds that have been found to have the potential to partition to the sludge include chlorobenzene, ethylbenzene, toluene and tetrachloroethylene (Kincannon et al., 1983; Petrasek et al., October, 1983; Hannah et al., 1986).

The adsorption rate can be predicted by the following formula (Namkung, et al., 1987):

$$R_{ads} = -Q_w X_w q$$

where:

R_{ads} = rate of compound adsorption, gram/day
Q_w = wasted sludge rate, m^3/day
X_w = concentration of wasted cells, grams VSS/m^3
q = sorption density for compound, gram/gram VSS

The sorption density has been found to be proportional to K_{ow} and the fraction of organic solids. A proposed relationship is (Namkung, et al., 1987):

$$q = 3.345(10^{-7})K_{ow}$$

Therefore, the equation for predicting the adsorption rate is:

$$R_{ads} = -3.345(10^{-7})Q_w X_w K_{ow}$$

3.1.3 Biodegradation of Organic Compounds

Aerobic biodegradation of hazardous compounds is the transformation of the compound into minerals, carbon dioxide and water (Kobayashi et al., 1982).

Factors that affect biodegradation of organic compounds include (Kincannon et al., 1983; U.S. EPA, 1986):

-dissolved oxygen level in aeration basin,
-temperature,
-pH,
-salinity,
-concentration of particulate material,
-concentration of compound,
-solubility of compound,
-volatility of compound,
-hydrophobicity of the compound,
-compound nutritional value to microorganisms,
-quantity of biologically active solids and
-acclimation of MLVSS.

Most data concerning biodegradation of toxic organics are for acclimated systems. An acclimated system is one in which the microorganisms have been exposed to the compounds and are

functioning up to their potential for the conditions. Biodegradation for an acclimated system can be predicted by using a modified Monod expression (Namkung et al., 1987):

$$R_{bio} = -kXvS/(K_s + S)$$

where:

R_{bio} = rate of biodegradation, gram/day
k = maximum specific substrate utilization rate, gram/gram VSS day
X = active cell concentration, gram/gram VSS/m^3
K_s = Monod half-velocity constant, gram/m^3
S = compound's concentration in aeration basin, gram/m^3
v = volume of aeration tank, m^3

In general, compounds that metabolize slowly are more resistant to biodegradation in conventional aeration basins. Also, larger, more complicated molecules and manmade compounds are usually less biodegradable (Kobayashi et al., 1982). The kinetic constants for the model must be estimated or assumed, as few values have been experimentally determined.

3.1.4 Overall Removal of Organic Compounds

The removal of organic chemicals from an activated sludge treatment process can be modeled by combining the removals for each individual significant mechanism (Namkung et al., 1987):

$$Q(S - S_o) = R_{bio} + R_{ads} + R_{vol}$$

where:

S_o = individual compound concentration in influent, gram/m^3
Q = wastewater flow to aeration tank, m^3/day

3.1.5 Unacclimated Conditions

Many wastewater treatment plants are subject to shock loadings from the batch discharge of compounds from industry. This results in unacclimated conditions.

Studies done by the U.S. EPA, 1986, have found that unacclimated conditions do not hinder the removal of many common organic substances. The few exceptions include pentachlorophenol, 1,1,2,2-tetrachloroethane, nitrobenzene, bis(2-chloroethyl)phthalate and 1,2-dichloroethane. Tabak et. al., 1981, also found that bis(2-chloroethyl)phthalate was not significantly biodegraded until the microorganisms became

adaptive. Most other phenolic, phthalate ester and naphthalene compounds that U.S. EPA, 1986 investigated were biodegraded with rapid or gradual adaptation. The technique used for these studies was a static culture flask biodegradation screening kit. King et al., 1985, tested six organic chemicals to find if a three month acclimation period enhanced biodegradation. The only apparent acclimation occurred for pentachlorophenate (PCP). The microorganisms showed no acclimation for cetyl trimethyl ammonium bromide (CTAB), cetyl pyridinium chloride (CPC), sodium diethyl dithiocarbamate(DDTC), p-benzoquinone (PB) and dichlorophen (DCP).

3.2 REMOVAL OF RCRA COMPOUNDS BY EFFLUENT FILTRATION

Few studies have been conducted to investigate the removal of organic compounds by gravity filtration. Because filtration is a physical process, only the organic compounds that attached to solids would be expected to be removed. Hannah et al., 1986, studied the removal of volatile and semivolatile organics by a primary clarification plus filtration system. Their results indicated that this system was not effective for the removal of volatile compounds but was slightly effective for the removal of semivolatile compounds. However the authors concluded that such a process was not a good choice for the removal of organic toxics.

3.3 INHIBITORY ORGANIC RCRA COMPOUND CONCENTRATIONS

The inhibitory concentration of a compound, which is the concentration that results in effluent COD, BOD or ammonia levels higher than permitted, depends on the particular compound, the system's degree of acclimation and the operating parameters of the treatment process. The inhibition usually results because of the toxic effect of the compounds on the microorganisms that use carbon and nitrogen for their energy source. Kincannon et al., 1983, spiked tetrachloroethane (highly volatile) into a bench-scale activated sludge system at a concentration of 201 mg/L without any adverse effect on the system. However, for most experimental systems, the total concentration of organic RCRA compounds has been less than 10 mg/L (Petrasek, et al., September, 1983; U.S. EPA, 1986).

3.4 NITROGEN TRANSFORMATIONS

The remaining sections in this review discuss the nitrogen removal process and the effect RCRA compounds have on it. The removal of nitrogen from sewage is becoming more common, and thus it is important to investigate the process and the

treatability of RCRA compounds that are discharged into a treatment plant.

Nitrogen containing compounds can easily change from one oxidation state to another by either a biological transformation or chemical reaction. Most nitrogen associated with plants and animals is in the form of organic nitrogen and ammonia. These forms are readily oxidized biologically to more stable compounds under conditions existing in receiving waters. Figure 3.1 shows the nitrogen cycle.

Ammonia in a lake or river has a nitrogenous oxygen demand (NOD), just as organic carbon has a carbonaceous oxygen demand (COD). This demand can cause a depletion of oxygen from lake or river water, which can threaten the survival of aquatic organisms. Of equal importance is biostimulation caused by nitrogen containing compounds when discharged into surface waters. Because nitrogen is a nutrient, excessive amounts could cause excessive plant growth resulting in eutrophication. Eutrophication results in odor problems, poor esthetics and lower dissolved oxygen levels. Also, the combination of an increase in pH and ammonium ion (NH_4^+) can result in the formation of ammonia (NH_3) which has been found to be toxic to fish. Other concerns include the decrease in disinfection efficiencies in water, as ammonia will combine with free chlorine to form chloramines. Furthermore, nitrogen in the form of nitrate can result in methemoglobinemia (a blood disorder) that affects infants less than three months old (Andrews, 1972 and Brown et al., 1975).

3.4.1 Biological Transformation of Nitrogen

Three common biological transformations of nitrogen are generally recognized (Kincannon et al., 1983):

- -ammonification, organic nitrogen to ammonia,
- -nitrification, ammonia to nitrite and nitrate, and
- -denitrification, nitrate and nitrite to nitrogen gas.

Nitrite formation is very unstable and is seldom found in significant quantities. Therefore, nitrification is usually considered to be the transformation of ammonia to nitrate.

Nitrification is considered the most important nitrogen transformation mechanism in the wastewater treatment process, as nitrate is the most stable form of nitrogen, next to nitrogen gas. Nitrified wastes do not exert an NOD and water quality impacts are minimized. The emphasis of this study will, therefore, be on nitrification.

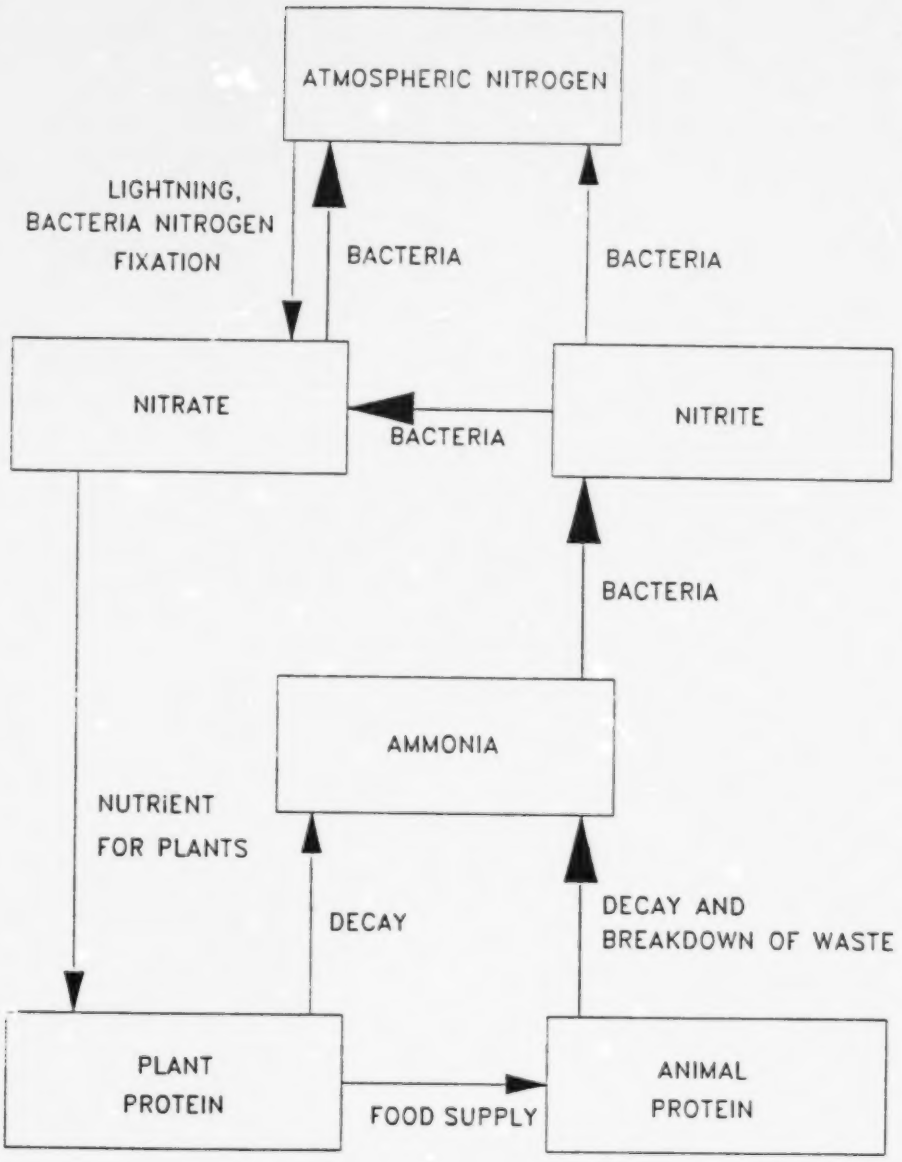


FIGURE 3.1, THE NITROGEN CYCLE

3.4.2 Nitrification

Nitrifying bacteria are autotrophic; they obtain their energy from inorganic compounds such as carbon dioxide, bicarbonate or carbonate (alkalinity) (Wang et al., 1978). The two bacteria responsible for nitrification are the Nitrobacter and Nitrosomonas. Nitrosomonas are responsible for converting the ammonia into nitrite:

$$NH_4^+ + 1.5O_2 \text{ -----> } 2H^+ + H_2O + NO_2^-$$

Nitrobacter are responsible for converting the nitrite into nitrate:

$$NO_2^- + .5O_2 \text{ -----> } NO_3^-$$

The overall reaction for nitrification is thus: (Brown et al., 1975)

$$NH_4^+ + 2O_2 \text{ -----> } NO_3^- + 2H^+ + H_2O$$

Alkalinity is depleted by the nitrification process:

$$NH_4^+ + 2O_2 + HCO_3^- \text{ -----> } CO_2 + NO_3^- + H^+ + 2H_2O$$

Approximately 7.14 mg/L of alkalinity as $CaCO_3$ are destroyed per mg of ammonia-N oxidized (Brown et al., 1975). Therefore, nitrification reduces HCO_3^- levels and increases H_2CO_3 levels, which results in a pH drop. However, if the aeration basin is not covered, aeration will strip the CO_2 and help to stabilize the pH (Brown et al., 1975; Wang et. al., 1978).

The oxygen requirement for the Nitrosomonas is 3.43 Kg to oxidize 1 Kg ammonia to nitrite, while the Nitrobacter require 1.14 Kg of oxygen. Therefore, there is a total theoretical requirement of 4.57 Kg of oxygen per Kg ammonia (Wang et al., 1978). To oxidize a Kg of organic carbon, typically 1.45 Kg of oxygen is required.

3.4.3 Design of Biological Nitrification Systems

Many different biological wastewater treatment processes are able to support the growth of nitrifying bacteria. The general requirements that provide an environment conducive to nitrification are (Smith, 1977):

- -a dissolved oxygen content above 2 mg/L,
- -pH in the range of 6.5 - 8.5,
- -7 mg/L of alkalinity per mg/L of ammonia to be oxidized (Wang et. al., 1978),
- -high solids retention time (SRT),
- -absence of inhibiting heavy metal and toxic organics and
- -temperatures above 15^{o}C (WPCF, 1982).

The effectiveness of nitrification and carbonaceous BOD removal for specific processes are listed below (Brown et al., 1975).

- -Conventional activated sludge: the SRT is generally too low to promote good nitrification but high enough to provide adequate COD removal.
- -Extended aeration: the long SRT and the flexibility of the process can be conducive for partial nitrification and COD removal.
- -Two stage process: carbonaceous BOD reduction and nitrification generally occur in different processes, employing either activated sludge or trickling filters. This process is very effective for both carbonaceous BOD removal and nitrification as the proper environment can be maintained for each process.
- -Contact stabilization process: in this process carbonaceous BOD adsorbs onto activated sludge and is oxidized when the sludge is aerated. This process is not effective for nitrification because of the short retention time, and ammonia will not adsorb onto the sludge.
- -Sequencing batch reactor: this process can be very effective for both carbonaceous BOD reduction and nitrification if the proper sequence is utilized (Alleman et al., 1980).

3.4.4 Other Nitrogen Removal Processes

Although biological nitrogen removal is most common for a wastewater treatment plant, other techniques can be used (Kincannon, et al., 1983).

-Breakpoint Chlorination: oxidation of ammonia to nitrogen gas using chlorine as the oxidizing agent,

$$3Cl_2 + 2NH_4^+ \text{-----> } N_2 + 6HCl + 2H^+.$$

For practical applications, 10 mg/L of Cl is required for 1 mg/L of ammonia-N. The process can be 100% effective. A dechlorination step is usually required before discharging, and chlorinated compounds can be formed. Also, chlorine can oxidize organics. Therefore, organics can exert a high chlorine demand which could increase the chemical cost significantly.

-Selective ion exchange: adsorption of nitrogen using a column of clinoptilolite or zeolite. The process can be very effective but may not be economical on a large scale.

-Air stripping: by increasing the pH of a solution containing ammonium (NH_4^+) to 10 or 11, ammonia (NH_3) is produced and can be released into the atmosphere if the water is partitioned into small droplets. This process is effective in warm climates. pH adjustment is required before discharging the denitrified waste.

3.5 THE IMPORTANCE OF A SYSTEM'S SRT FOR THE REMOVAL OF ORGANIC COMPOUNDS

Kincannon et al., 1983, compared the performance of bench-scale wastewater treatment plants with SRTs of 2, 4 and 6 days for the removal of organic chemicals. They found that no significant inhibition of BOD_5, TOC or COD removal occurred for phenol, benzene, 1,2-dichloroethane, 1,3-dichlorobenzene and 2,4-dinitrophenol, among others, for any of the three SRTs. However, the 4 and 6 day SRTs did show increased removals for nitrobenzene. Hill et al., 1986, found that sludge ages of 4, 6 and 9 days did not improve the removal of chlorophenoxyherbicides. Melcer, et. al., 1988, tested pentachlorophenol (PCP) removal at concentrations from 0.1 to 12 mg/L in bench-scale continuous flow activated sludge systems with SRTs of 5, 10, 15 and 20 days. The removal was incomplete for a 5 day SRT at an influent concentration of 0.1 mg/L but PCP

was removed to below 10 ug/L for the other SRTs tested, up to an influent concentration of 12 mg/L.

3.6 INHIBITION OF THE NITRIFICATION PROCESS CAUSED BY ORGANIC RCRA COMPOUNDS

Nitrifying bacteria are more sensitive to organic RCRA compounds than the microorganisms that are commonly involved in carbonaceous BOD removal. Wang et al., 1978, stated that phenol and cresol at 20 mg/L or more and trace amounts of halogenated solvents can be inhibitory to the nitrification process. A study by Smith, 1977, investigated the concentration of organic compounds that produced 75% inhibition of nitrification on unadapted sludge. They found that concentrations of 840 mg/L of acetone, >150 mg/L of 2,4-dinitrophenol and 5.6 mg/L of phenol caused 75% reductions in nitrification. King et al., 1985, also found a broad range of inhibiting concentrations, including >40 mg/L for PCB and 2 mg/L for dichlorophen.

SECTION 4
EXPERIMENTAL DESIGN

4.1 SYSTEM DESIGN AND OPERATIONS

To carry out the objectives of this project, two 3.78 L/min pilot-scale extended aeration wastewater treatment plants, with dual media secondary effluent filters were constructed and operated at the USEPA Test and Evaluation Facility (T&E) in Cincinnati, Ohio, by University of Cincinnati technicians and a Graduate Researcher. Figure 4.1 shows a schematic of the two systems.

The influent to each system was primary effluent from the Mill Creek Wastewater Treatment Plant (Metropolitan Sewer District, MSD) in Cincinnati, Ohio, primary effluent from one of two pilot scale conventional activated sludge systems at the T & E facility (conventional, EPA contract #68-03-4038) or a combination of both. Each system had a set of two feed pumps and two needle valves to control the influent flow and select the desired primary effluent. Consequently, the influent to the system could be strictly Mill Creek primary effluent, primary effluent from the conventional pilot system at T&E or a combination of both. Because only the conventional pilot systems were being spiked with the RCRA compounds, this design allowed spiking of the extended aeration systems continuously or intermittently at various concentrations.

The aeration basins for both systems were each 0.61 m wide, 4.6 m long and 1.37 m deep, for a total volume of 3844 L per basin. The hydraulic retention time was 16.8 hours. The basins were divided into seven passes separated by baffles at a maximum distance of 0.6 m. Each pass had a coarse air diffuser that provided aeration and mixing. The influent and recycled activated sludge entered in the first pass, slightly above the water surface. The basins were covered with plexiglas and off-gases vented out of the facility.

The secondary clarifiers were 1.80 m deep and had a diameter of 0.91 m. The bottom was conical to aid in sludge collection. The resulting overflow rate was 8.34 $m^3/m^2/day$. Sludge was removed by a mechanical scraper. Eight liters of excess activated sludge were wasted six times a day through the recycle line for a total of 48 L/day for each system. This wasting rate and a recycle ratio of about 0.6 allowed for an average solids retention time of 21 days. Scum was manually removed from the top of the clarifiers as necessary.

The dual media effluent filters are shown in Figure 4.2. Each is 2.74 m high and has a cross sectional area of 929 square cm. A 36 cm layer of sand and a 48 cm layer of anthracite coal provide the filtration. Filter effluent is collected in a 945 L high density polyethylene molded plastic tank and reused for the backwash cycle. The filters were backwashed daily for 10 minutes. A 5 minute air only and 5 minute water only cycle was

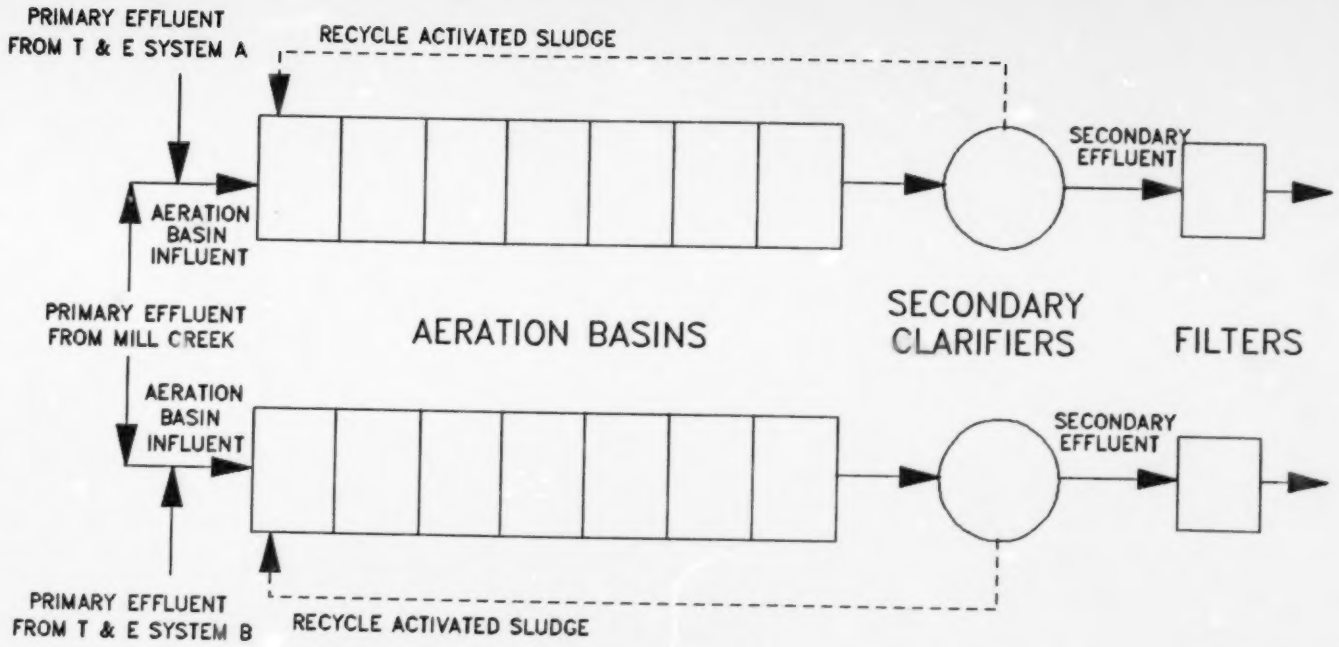


FIGURE 4.1, SCHEMATIC OF NITRIFICATION SYSTEM

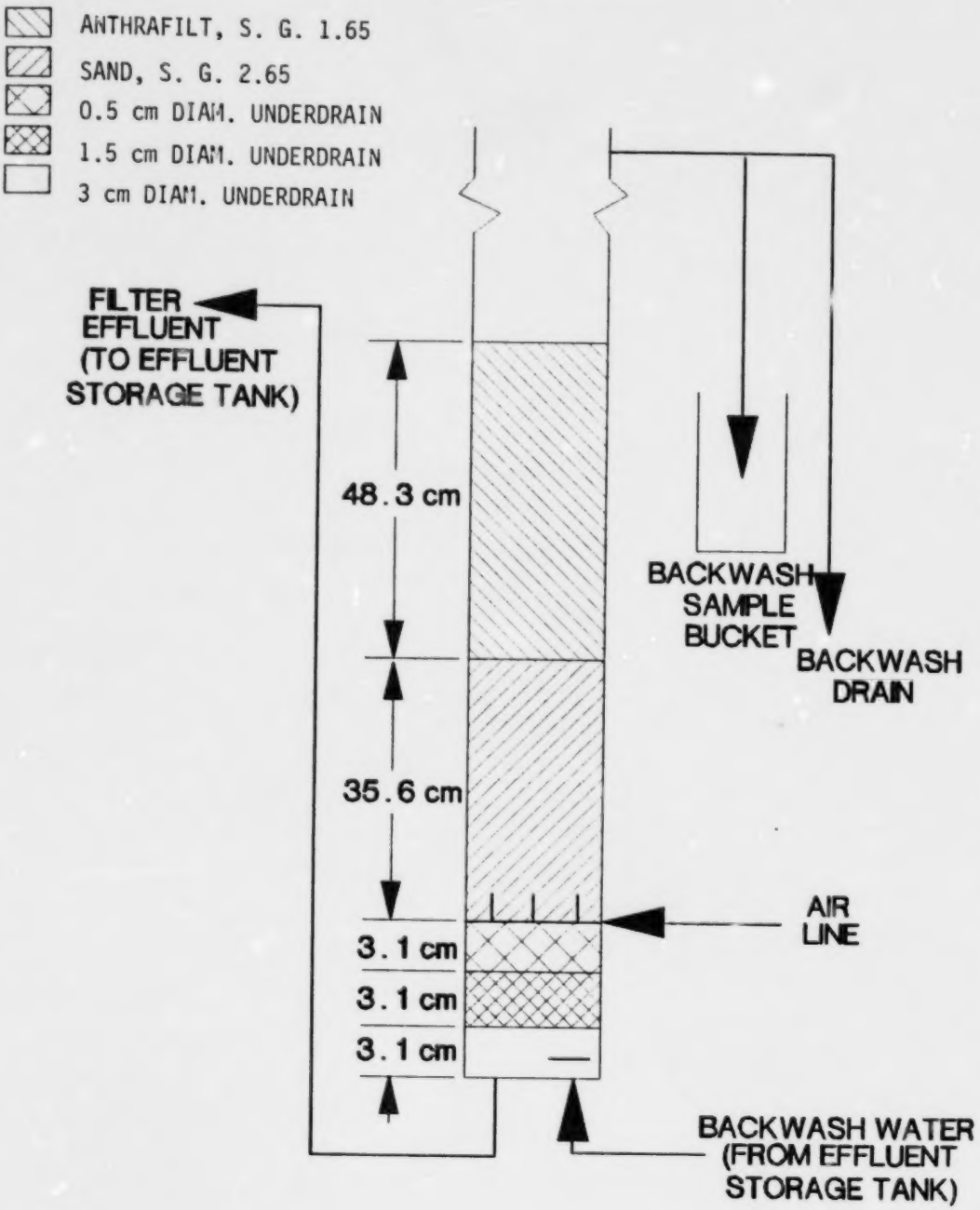


FIGURE 4.2, DUAL MEDIA EFFLUENT FILTER

utilized. A small portion of the backwash was collected for analysis in a sample bucket during the backwash cycle.

The design parameters and actual operating values are presented in Table 4.1

4.2 RCRA COMPOUND SPIKING SYSTEM

The 28 RCRA compounds were spiked into the conventional pilot systems at several different concentrations ranging from 0.25 to 1.0 mg/L of each organic. Table 4.2 lists each compound and a description of its properties. These compounds were selected in order to ensure a good representation of RCRA compounds with a wide range of properties. The resulting ranges were:

-Henry's Coefficient: 0.0000 to 0.944
-Log Octanol/Water Coefficient: 0.07 to 8.69

The significance of each property was discussed in Section 3.1.

The RCRA compound spike system consisted of a 416 L stainless steel vented storage tank located in a fenced area outside the T & E facility. The chemicals were mixed and stored in this tank. Two 37.8L stainless steel feed tanks (one for each system) located inside the facility were used to spike the conventional systems. A FMI Lab piston pump delivered the spike into degritted, hydrasieved raw wastewater (obtained from the adjacent Mill Creek Wastewater Treatment Plant). Each system had its own piston pump. The spike pump's calibration was checked at least three times a week. The sewage and chemicals were mixed with a Chemineer Kenics static mixer and passed through two 1557 L tanks. The combination of sewage and spike was recirculated through the tanks by a high speed circulation pump. This helped simulate the contact time and conditions in the sewer system. From the storage tanks the spiked sewage was pumped as influent to the primary clarifiers of the conventional system.

4.3 PHASES OF THE STUDY

This project was divided into three phases:

1) process interference caused by organic RCRA compounds,
2) fate and treatability of organic RCRA compounds and
3) the removal of organic RCRA compounds by dual media effluent filtration.

A description of each phase follows.

TABLE 4.1, DESIGN PARAMETERS

PARAMETER	DESIGN	ACTUAL ACCLIMATED*	S.D.	ACTUAL UNACCLIMATED**	S.D.
Flow, L/min	3.78	3.51	0.45	3.77	0.41
SRT, days	20	20	2	21	3
Hydraulic Detention Time, hours	16.8	18		17	
MLTSS, mg/L	4000	2519	398	2596	482
WAS Total Suspended Solids, mg/L	8000	7851	1798	8119	1759
Recycle Ratio	1.0	0.57		0.53	
NH3-N inf., mg/L	20	21.1	7.4	21.4	7.7

*AVERAGE FOR JANUARY 1, 1988 TO MAY 1, 1988
**AVERAGE FOR JANUARY 1, 1988 TO MARCH 3, 1988

S.D.: STANDARD DEVIATION

TABLE 4.2, TESTED COMPOUNDS AND PROPERTIES

COMPOUND	APPEARENCE	USES	LOG OCTANOL/ WATER PARTITION	HENRY'S COEFF.	ANALYSIS TYPE
Acetone	Colorless liquid	Paints, Varnishes, Sealants, Organic Solvents	0.81	0.0001	Volatile
Bis(2-Ethylhexyl) Phthalate	Colorless to yelow liquid	Solvent	8.69	0.0000	Semi-vol.
Butyl benzyl phthalate	Clear, oily liquid	Plasticize or flexibilize synthetic resins	4.80	0.0000	Semi-vol.
Carbon tetrachloride	colorless liquid	Fire extinguisher, dry cleanin, refrigerants, aerosols, propellants	2.64	0.944	Volatile
Chlorobenzene	colorless liquid	Solvent recovery, insecticide	2.84	0.2035	Volatile
Chloroform	colorless liquid	Refrigerants, propellants, plastics,ansesthetic, solvent, sweetener, fire extinguisher, insecticide, circuitry	1.97	0.1573	Volatile
Cyclohexanone	Colorless liquid	solvent for insexticides	0.81	0.0001	Semi-vol.
1,2-Dichloroethane	Colorless liquid	solvent, refrigerant organic synthesis	1.53	0.0502	Volatile
1,2-Dichloropropane	Colorless liquid	Solvent, lead scavenger	1.94	0.0945	Volatile
1,4-Dichlorobenzene	Colorless or white crystal	Moth repellent, air deodorizer pesticide	3.36	0.0000	Semi-vol.
2,4-Dimethylphenol (2,4-Xylenol)	Colorless needles	Plastics, resins, solvents rubber chemicals	2.5	0.0000	Semi-vol.
2,4-Dinitrophenol	Yellow rhombic crystal or needles		1.54	0.00	Semi-vol.
Ethylbenzene	Colorless liquid	Solvent, asphalt constitute	3.15	0.263	Volatile
Furfural	Colorless to yellow liquid	Solvent, shoe dyes, weed fungicide, flavoring killer	0.81	0.0001	Volatile
Methyl ethyl ketone	Colorless liquid	Solvent, paint stripper, wax, cleaning fluid, printing carrier and catalyst	0.26	0.001	Volatile

TABLE 4.2 (continued)

COMPOUND	APPEARENCE	USES	LOG OCTANOL/ WATER PARTITION	HENRY'S COEFF.	ANALYSIS TYPE
Methyl isobutyl Ketone	Colorless liquid	Solvent	-	0.0042	Volatile
Methylene chloride	Colorless liquid	Paint stripper, solvent, aerosols, photographic film, refrigerant	1.25	0.1198	Volatile
Naphthalene	Colorless liquid	Solvent			
Nitobenzene	Yellow liquid	Solvent recovery, rubber chemicals, photographic chemicals, metal solvent, shoe polish	1.86	0.0005	Semi-vol.
4-Nitrophenol	Colorless to yellow crystal	Fungicide, organic synthisizer	1.96	0.0000	Semi-vol.
Phenol	Colorless to brown-black	Solvent	1.47	0.0000	Semi-vol.
Toluene	Colorless liquid	Solvent	2.69	0.2729	Volatile
Tetrachloroethylene	Colorless liquid	Dry cleaning, metal degreasing solvents, remove ink	2.42	0.523	Semi-vol.
Tetrahydrofuran	White liquid	Solvent	0.07	0.0006	Volatile
1,1,1-Trichloroethane	Colorless liquid	Solvent	2.49	0.1631	Volatile
1,1,2-Trichlorethane	Corless liquid	Solvent for organic and rubber materials	2.06	0.0406	Volatile
Trichloroethylene	Colorless gas	dry cleaning. metal degreasing solvents, refrigerant	2.42	0.523	Volatile
o-Xylene	colorless liquid	Polyester, solvent recovery aviation gasoline, protective coating lacquers, enamels, rubber cement	2.77	0.215	Volatile

4.3.1 Process Interference Caused by Organic RCRA Compounds (Phase 1)

The effect of the 28 RCRA compounds on the ability of a pilot-scale extended aeration wastewater treatment plant to adequately treat the wastewater was investigated. The process control variables used to evaluate the system's performance were:

-Chemical Oxygen Demand (COD),
-Nitrogen Series,
  Nitrate
  Ammonia
  Total Kjeldahl Nitrogen (TKN)
-Total Phosphorus (TP).

These parameters were measured approximately three times a week on the aeration basin influent and effluent (except COD) and the secondary clarifier effluent. The performance of the system was compared under five different spike conditions.

-Baseline: system performance before any spike had been added. Total spike concentration of 0 mg/l. Obtained with MSD's primary effluent only.
-Total spike concentration of 1.8 mg/L. Calculated by summing the amount of each compound found for each event and taking the average of all three events. Obtained with a MSD to T & E ratio of 6:4.
-Total spike concentration of 4.8 mg/L. Calculated as above. Obtained with T & E's primary effluent.
-Total spike concentration of 19.2 mg/L. Calculated based on the spike pump's setting and, therefore, not actually measured. Obtained with T & E's primary effluent.
-Discontinuation of spike. Obtained with T & E's effluent only.

4.3.2 Fate and Treatability of Organic RCRA Compounds (Phase 2)

In this phase of the project, the concentration of the 28 RCRA compounds at different stages of the treatment process were studied. The initial concentration was selected so as not to cause any process interference to the system. This concentration was determined from literature and a preliminary run with the conventional activated sludge system. During the preliminary test the calculated spike concentration into the

conventional system was 1 mg/L for each compound. All 28 compounds were mixed together. This concentration apparently caused disruption to nitrification, therefore the concentration in the conventional system was dropped to 0.25 mg/L for each compound (EPA contract # 68-03-4038). Because a combined nitrification/BOD reduction wastewater treatment plant is thought to be more sensitive to toxics than a conventional activated sludge system, the concentration was further decreased in the feed to the nitrification system. This decrease was obtained by diluting the spiked feed entering the nitrification system aeration tank. The resulting spike concentration was about 0.1 mg/L for each compound, assuming minimal removal by the primary clarifier of the conventional system. To maintain this concentration, the ratio of MSD primary effluent to T & E primary effluent was 6 to 4 (MSD primary effluent was assumed to have no background concentration of the tested compounds). This ratio was held as constant as possible during this phase, as the purpose was to find the fate and treatability of the spiked RCRA compounds.

Once the systems were started and had reached steady state, one of the nitrification systems was fed continuously with the RCRA compounds to allow the microorganisms to become acclimated to the toxics. The other system was not spiked so the microorganisms would not become acclimated.

Steady state, defined as a constant SRT of 20 days for a week without adjustments to the wasting schedule or the recycle ratio, was reached on January 1, 1988 for both systems. Spiking began for the acclimated system on January 11, 1988. This system was spiked continuously throughout the study.

Data were obtained from three sampling events:

Event 1: February 2-3, 1988,
Event 2: February 17-18, 1988,
Event 3: March 1-2, 1988.

A sampling event consisted of a 48 hour time period. For the first 24 hours the unacclimated system was spiked with the RCRA compounds. For each 48 hour sampling event, the following samples were taken every 4 hours and composited for analysis of the RCRA compounds.

- -aeration basin influent (combination of primary effluents from the conventional activated sludge plant at T&E and MSD)
- -secondary clarifier influent
- -secondary clarifier effluent
- -waste activated sludge (same as recirculated activated sludge)

4.3.3 The Removal of Organic RCRA Compounds by Dual Media Effluent Filtration (Phase 3)

In this phase, the removal of the organic RCRA compounds by dual media effluent filtration was investigated. To assess the effectiveness of the filters, the concentration of each compound was measured in the secondary effluent (before entering the filter) and in the filter effluent. Date were obtained for two secondary effluents:

- -secondary effluent obtained from the acclimated nitrification system, which was being spiked at a total concentration into the aeration basin of 1.8 mg/L from day 1 of the project to day 62 and

- -secondary effluent obtained from the acclimated conventional system at the T & E facility, which was being spiked at a total concentration into the aeration basin of 4.8 mg/L from day 63 to 90 of the project.

Samples were collected for RCRA compound analysis eleven times, three for the nitrification secondary effluent and eight for the conventional.

SECTION 5
ANALYTICAL PROCEDURES

5.1 CONTROL VARIABLES

The control tests used to operate the systems and monitor their performance are listed below (USEPA, T & E, 1987):

pH: measured for primary and secondary effluent three times a day with an Orion pH meter in accordance with Method 150.1, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020.

Alkalinity: measured as mg/L $CaCO_3$ by titrating the sample with H_2SO_4 until a pH of 4.5 was reached, in accordance with Method 310.1, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020. Samples were analyzed once a day on a 24 hour composite made up of six samples collected every four hours. Primary and secondary effluents were analyzed.

Dissolved Oxygen: measured as mg/L of oxygen for all seven passes in the aeration tanks three times a day with a YSI D.O. meter in accordance with Method 360.1, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020.

Dissolved Oxygen Uptake Rate: measured as mg/L-hr oxygen on the aeration basin's effluent three times a day with a YSI D.O. meter attached to a chart recorder in accordance with Method 213A, Standard Methods for the Examination of Water and Wastewater, 16th ed., APHA-AWWA-WPCF, pp. 127-129.

Settled Sludge Volume: measured as ml/L three times a day on the aeration basin's effluent by allowing the sludge to settle undisturbed for 30 minutes in accordance with Method 213C Standard Methods for the Examination of Water and Wastewater, 14th ed., APHA-AWWA-WPCF, 1975, p. 128.

Total and Volatile Suspended Solids: measured as mg/L of dry solids for primary, secondary and filter effluents, secondary aeration basin's effluent and recirculated activated sludge once a day using a 24 hour composite made up of 6 samples collected every 4 hours in accordance with Method 209D, Standard Methods for the Examination for Water and Wastewater, 16th ed., APHA-AWWA-WPCF, 1985, pp. 99-100.

Flow Rates: measured as L/min for the effluent and recirculated activated sludge flows three times a day by timing the flow into a graduated cylinder.

Values calculated from these control variables include:

Solids Retention Time (SRT):

$$SRT\ (days) = \frac{(basin\ vol.)(MLSS)}{(WAS\ vol.)(TSS\ WAS) + (eff.\ vol.)(TSS\ eff.)}$$

where

eff.= secondary effluent (L/day)
MLSS = mixed liquor suspended solids (mg/L)
TSS = total suspended solids (mg/L)
vol. = volume (L)
WAS = waste activated sludge (L/day)

Sludge volume index (SVI):

$$SVI(ml/g) = \frac{(ssv)(1000)}{MLSS}$$

where

ssv = settled sludge volume (ml/l)
1000 = conversion for mg to g

5.2 PROCESS PARAMETERS

The process control variables used to evaluate the system's performance were pH, alkalinity, chemical oxygen demand (COD), total phosphorus (TP), ammonia, nitrite, nitrate and Total Kjeldahl Nitrogen (TKN). PH and alkalinity were explained in Section 5.1. The methods used for the others are as follows:

COD: measured for primary, secondary and filter effluents three times a week. The sample was digested at 150^{O} C in dichromate and quantified spectrophotometrically by comparing to standards and blanks, in accordance to Method 410.4, Methods for Chemical Analysis of Water and Wastes, U.S. EPA, 1981. The values were determined colorimetrically by a Technicon Auto Analyzer II.

TP: measured for primary and secondary effluents and MLSS three times a week by heating the sample in a sulfuric acid solution containing K_2SO_4 and $HgSO_4$ followed by preparation of the reduced antimony-phospho-molybdate complex and comparing colorimetrically with standards and blanks using a Technicon AutoAnalyzer. This procedure is in accordance with Method 365.4, Methods for Chemical Analysis of Water and Wastes, U.S. EPA, 1981.

Ammonia: measured on primary and secondary effluents and on mixed liquor three times a week as nitrogen. Ammonia reacts with alkaline phenol and hypochlorite to form indophenol blue in proportion to the original ammonia concentration as described by Method 350.1, Methods for Chemical Analysis of Water and Wastes, U.S. EPA, 1981. The reacted samples are compared to standards colorimetrically using a Technicon Continuous Flow Analyzer System Interfaced to an IBM XT personnel computer.

Nitrate: measured as nitrogen for primary and secondary effluents three times a week by reducing the nitrate to nitrite with hydrazine sulfate. The nitrite originally present in the sample and the newly formed nitrite are transformed into a colored azo dye by adding sulfanilamide and N-(1-naphthyl)- ethylenediamine dihydrochloride in accordance with Method 353.1, Methods for Chemical Analysis of Water and Wastes, U. S. EPA, 1981. The transformed samples were colorimetrically compared to a set of standards using a Technicon Continuous Flow Apparatus interfaced with an IBM XT Personal Computer.

TKN: measured identically to TP except for standards.

5.3 TOXIC ANALYSES

Samples to be analyzed for volatile organic RCRA compounds were collected in 40 ml glass vials, capped with teflon lined septums, and stored at $4^{\circ}C$. Chilled samples were composited at the time of the analysis to produce a single sample. The sample was purged with an inert gas, helium, whereby the volatile organics were partitioned into the gas phase and adsorbed onto a multi-phase sorbent trap. After purging was complete, the carrier gas was reversed and the trap was heated rapidly. This caused the volatiles to desorb from the trap. The volatiles were then carried into a gas chromatograph by the carrier gas for separation and identification. A Finnigan DWA and Extrel ELQ400 GC/MS was used for the analysis. This method is in accordance with Method 8240, USEPA Method for Evaluating Solid Waste, SW846, 3rd ed. (PEI, 1988).

Semi-volatile compounds were composited directly into amber glass bottles with teflon or tin lined caps. This container was chosen because it would not deteriorate and contaminate the samples. The compounds were analyzed according

to Method 3520 of USEPA Methods for Evaluating Solid Waste, SW846, 3rd ed. In this method a 1L sample was used. The pH of the sample was adjusted to 11 and then mixed with the organic solvent, methylene chloride. This allows for the extraction of base/neutral organic compounds. The solution's pH was then reduced to 2 and acid compounds were extracted from the solution. The organics were then concentrated to 1 ml and the sample was injected into the GC/MS, Finnigan 5100 and Extrel ELQ 400 for separation and identification (PEI, 1988).

SECTION 6
RESULTS

6.1 INTERFERENCE CAUSED BY ORGANIC RCRA COMPOUNDS IN AN ACCLIMATED NITRIFICATION PROCESS

A pilot-scale extended aeration wastewater treatment system, as described in Section 4.1, was used for this study. The system provided an adequate environment for both carbonaceous BOD removal and nitrification. Primary effluent containing 28 RCRA compounds was spiked into the system's aeration basin; these compounds are listed in Table 4.2. Three spike concentrations were tested, 1.8 mg/L (total of all 28 compounds, averaged for three sampling events), 4.8 mg/L (average for three sampling events) and 19.2 mg/L (calculated based on spike pump ratios) as explained in Section 4.3. To measure the interference caused to the process by the organic RCRA compounds, COD, ammonia, nitrate and TKN were monitored, as well as the routine control variables.

6.1.1 Effect of Organic RCRA Compounds on Control and Operating Variables

Tables 6.1 and 6.2 show the control variables throughout the project at the different spike concentrations. The pH was in an acceptable range of 7.4 to 7.7 throughout the entire project. The lowest secondary effluent alkalinity was 67 mg/L as $CaCO_3$, which is above the minimum required as explained in Section 3.4.3. The mixed liquor total and volatile suspended solids (MLTSS and MLVSS) did vary from one spike concentration to another. The largest MLTSS and MLVSS occurred when the system was being spiked at a total concentration of 1.8 mg/L and were 2663 mg/L and 1908 mg/L, respectively. The lowest MLTSS and MLVSS were 2101 mg/L and 1490 mg/L, respectively, and occurred during the period when the spiking was discontinued.

Total suspended solids removal by secondary treatment was not adversely affected by the chemicals and actually increased with the higher spike concentrations. However all values are within 10% of each other, and the difference is probably a coincidence explained by the varying characteristics of the sewage.

Table 6.3 shows the system's operating parameters, throughout the entire project. The SRTs, flows, and D.O. concentrations were fairly similar from one test period to another.

TABLE 6.1, pH AND ALKALINITY FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			BASELINE DAY 1 TO 11	TOTAL SPIKE* 1.8 mg/L DAY 12 TO 66	TOTAL SPIKE* 4.8 mg/L DAY 67 TO 99	TOTAL SPIKE*,** 19.2 mg/L DAY 100 TO 108	TOTAL SPIKE 0 mg/L DAY 109 TO 122
ALKALINITY (mg/L AS $CaCO_3$)	ABI.	AVG.	256.2	235.4	249.7	261.6	271.7
		S.D.	35.8	42.5	77.5	22.1	31.9
		#	11/11	55/55	30/33	9/9	14/14
	SEC. EFF.	AVG.	67.4	86.2	94.8	137.4	102.6
		S.D.	43.8	27.3	34.3	14.0	34.7
		#	11/11	55/55	30/33	9/9	14/14
	% REDUCTION BY SEC.		73.7	63.4	62.0	47.5	62.3
pH	ABI.	AVG.	7.7	7.8	7.7	7.5	7.4
		S.D.	0.2	0.3	0.3	0.2	0.1
		# +	11/11	55/55	30/33	9/9	14/14
	SEC. EFF.	AVG.	7.5	7.5	7.6	7.7	7.6
		S.D.	0.3	0.3	0.1	0.1	0.1
		# +	11/11	55/55	30/33	9/9	14/14

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES USED/NUMBER OF SAMPLES
+: DAILY VALUE IS BASED ON A 3 DAY AVG.

ABI.: AERATION BASIN INFLUENT
SEC. EFF.: SECONDARY EFFLUENT

DAY 1 WAS JANUARY 1, 1988

TABLE 6.2, TOTAL SUSPENDED SOLIDS FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			BASELINE DAY 1 TO 11	TOTAL SPIKE* 1.8 mg/L DAY 12 TO 66	TOTAL SPIKE* 4.8 mg/L DAY 67 TO 99	TOTAL SPIKE*,** 19.2 mg/L DAY 100 TO 108	TOTAL SPIKE 0 mg/L DAY 109 TO 122
TSS (mg/L)	ABI.	AVG.	146	136	152	95	114
		S.D.	61	61	47	52	67
		#	11/11	53/55	33/33	9/9	14/14
	SEC. EFF.	AVG.	29	16	19	8	12
		S.D.	14	8	11	4	4
		#	11/11	54/55	32/33	9/9	14/14
	% REDUCTION BY SEC.		80.14	88.24	87.50	91.58	89.47
	MIXED LIQUOR	AVG.	2323	2663	2582	2273	2101
		S.D.	372	348	392	272	229
		#	11/11	53/55	33/33	9/9	13/14
VSS (mg/L)	MIXED LIQUOR	AVG.	1677	1908	1816	1604	1490
		S.D.	300	274	305	187	166
		#	11/11	53/55	29/33	9/9	12/14

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES USED/NUMBER OF SAMPLES

ABI.: AERATION BASIN INFLUENT
SEC. EFF.: SECONDARY EFFLUENT
TSS: TOTAL SUSPENDED SOLIDS
VSS: VOLATILE SUSPENDED SOLIDS

DAY 1 WAS JANUARY 1, 1988

TABLE 6.3, CONTROL VARIABLES FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID		CONCENTRATION OF 28 RCRA COMPOUNDS AND TEST PERIOD				
		BASELINE	TOTAL SPIKE* 1.8 mg/L	TOTAL SPIKE* 4.8 mg/L	TOTAL SPIKE*,** 19.2 mg/L	TOTAL SPIKE 0 mg/L
		DAY 1 TO 11	DAY 12 TO 66	DAY 67 TO 99	DAY 100 TO 108	DAY 109 TO 122
SRT (DAYS)	AVG.	19	21	21	21	20
	S.D.	3	3	3	1	2
	#	9/11	47/55	21/33	6/9	13/14
FLOW (l/MIN.)	AVG.	3.7	3.7	3.3	3.6	3.6
	S.D.	0.4	0.4	0.5	0.2	0.2
D.O. (mg/L O_2)	AVG.	6.4	6.6	6.7	5.9	5.7
	S.D.	1.0	1.2	1.2	0.5	0.7

*: CONCENTRATION INTO THE AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES INCLUDED/NUMBER OF SAMPLES

DAY 1 WAS JANUARY 1, 1988

6.1.2 Effect of RCRA Compounds on Process Control Parameters

Figures 6.1, 6.2, 6.3 and 6.4 are graphs of the process control parameters (COD, ammonia, nitrate and BOD, respectively) for the influent and effluent to and from the aeration basin for the test period. The only noticeable trend in these figures is the significant increase in secondary effluent ammonia and decrease in secondary effluent nitrate levels once the system had been spiked at a total concentration of 19.2 mg/L. Tables 6.4, 6.5, 6.6 and 6.7 quantify the process parameters for each period.

Table 6.4 indicates that COD reduction was not inhibited by any of the three spike concentrations tested, based on percent removals. The ammonia reduction by secondary treatment (Table 6.5) shows no inhibition until the 19.2 mg/L total spike concentration was tested. After spiking ceased, nitrification returned within a few days to its level before spiking. Table 6.6 provides a comparison with the expected ammonia reduction, based on the alkalinity reduction and the measured ammonia values. As indicated in Section 3.4.2, 7.14 mg/L of alkalinity is theoretically destroyed per mg/L of ammonia-N oxidized. A good correlation between the predicted and measured values was found. Table 6.7 indicates an increasing reduction in the formation of nitrate by secondary treatment with increasing spike concentration. TKN removal by secondary treatment also decreased with increasing spike concentration (Table 6.8). Figure 6.5 shows this graphically. Because the system was not allowed to fully acclimate at the highest concentration, curve fitting techniques cannot be utilized to predict inhibition at concentrations other than those measured. The trends from Figure 6.5 seem to indicate that nitrification was inhibited even at low spike concentration, although this could not be verified. The trends also indicate that ammonia reduction by secondary treatment was not inhibited until a spike concentration between 4.8 mg/L and 19.2 mg/L was reached.

Data for total phosphorus removal were also collected throughout the study. Table 6.9 shows these results. As expected, the organic RCRA compounds had a minimal effect on phosphorus removal. The main mechanism for its reduction is usually considered to be luxury uptake and precipitation, neither of which were designed for in the test system.

6.1.3 Comparison of Process Parameters Between the Baseline, Control and Spiked Operating Conditions

A parallel extended aeration system that was not spiked with the RCRA compounds for the first 38 days of the study served as a control. Results from this reactor are shown in Table 6.10. Because a control system was not available after

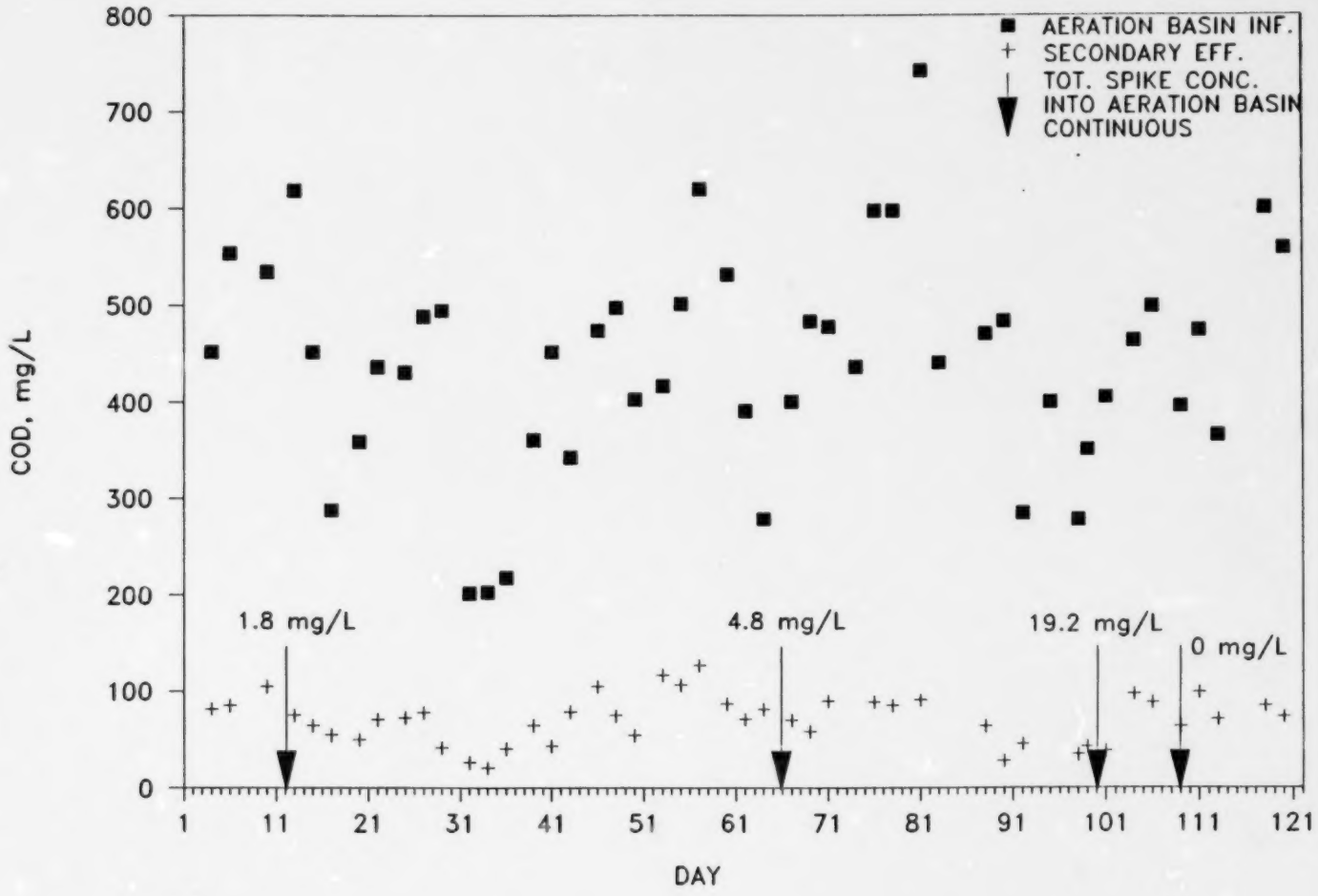


FIGURE 6.1. ACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT COD

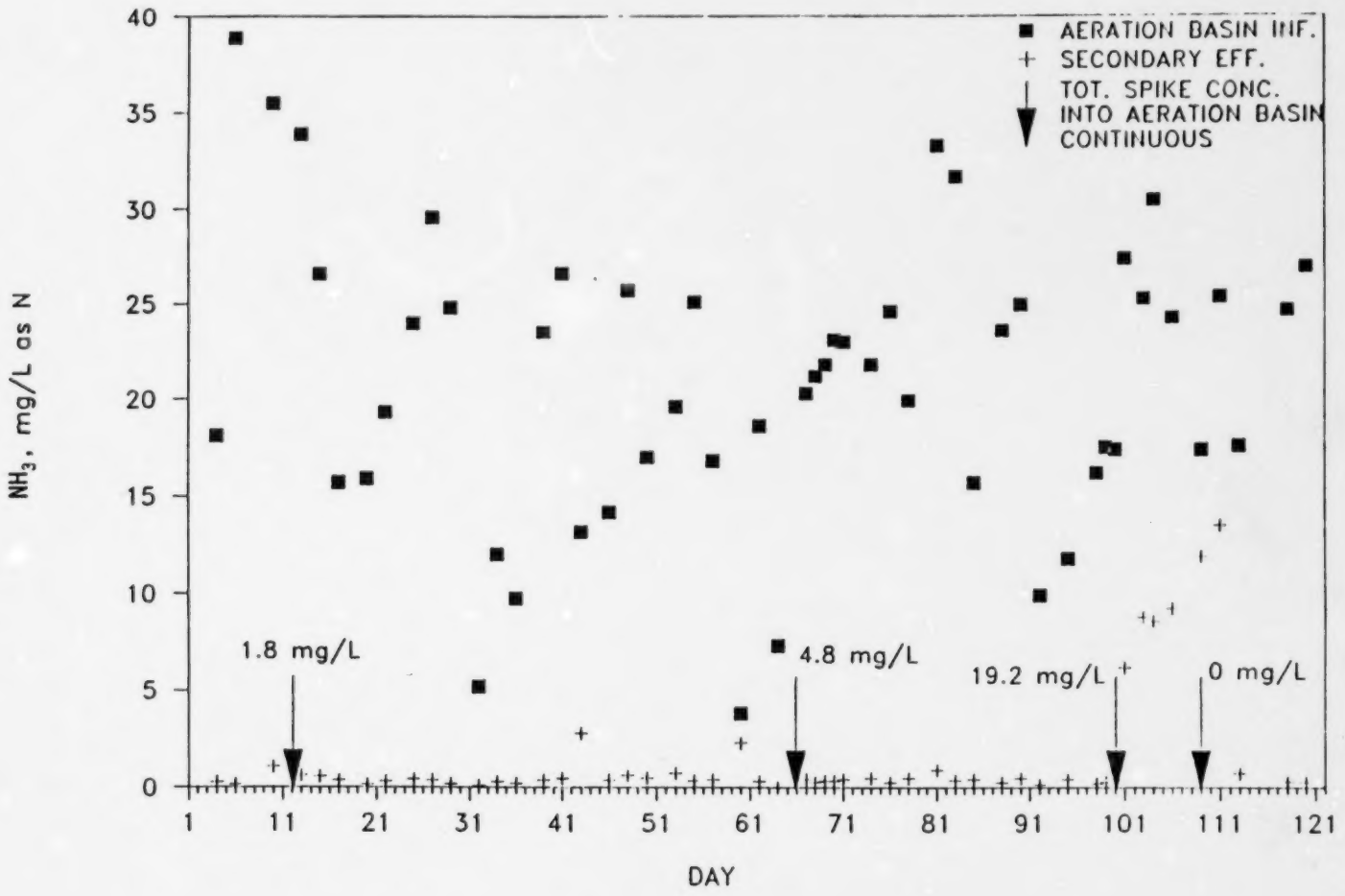


FIGURE 6.2. ACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT AMMONIA

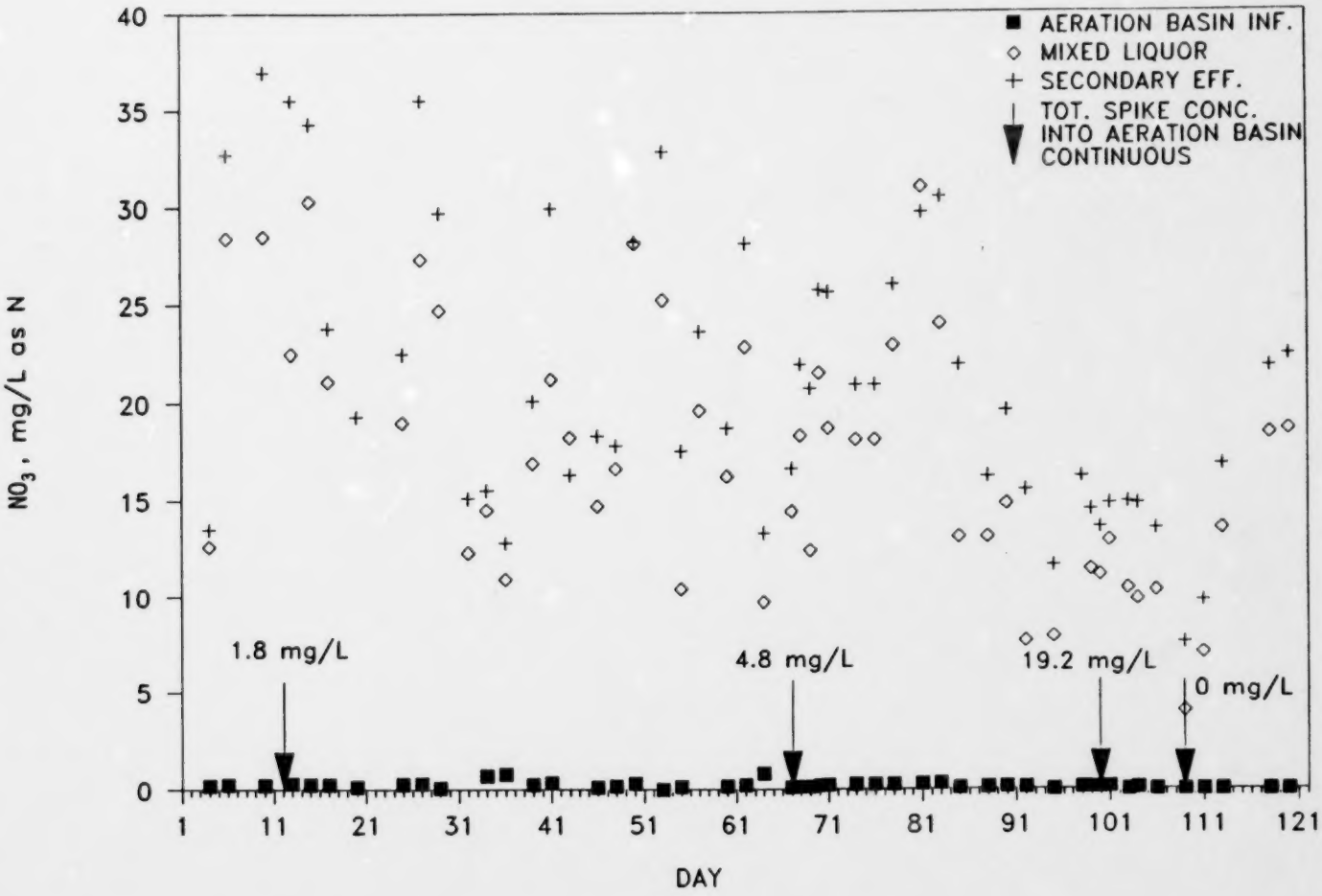


FIGURE 6.3. ACCLIMATED CONDITIONS, INFLUENT, EFFLUENT AND MIXED LIQUOR NITRATE

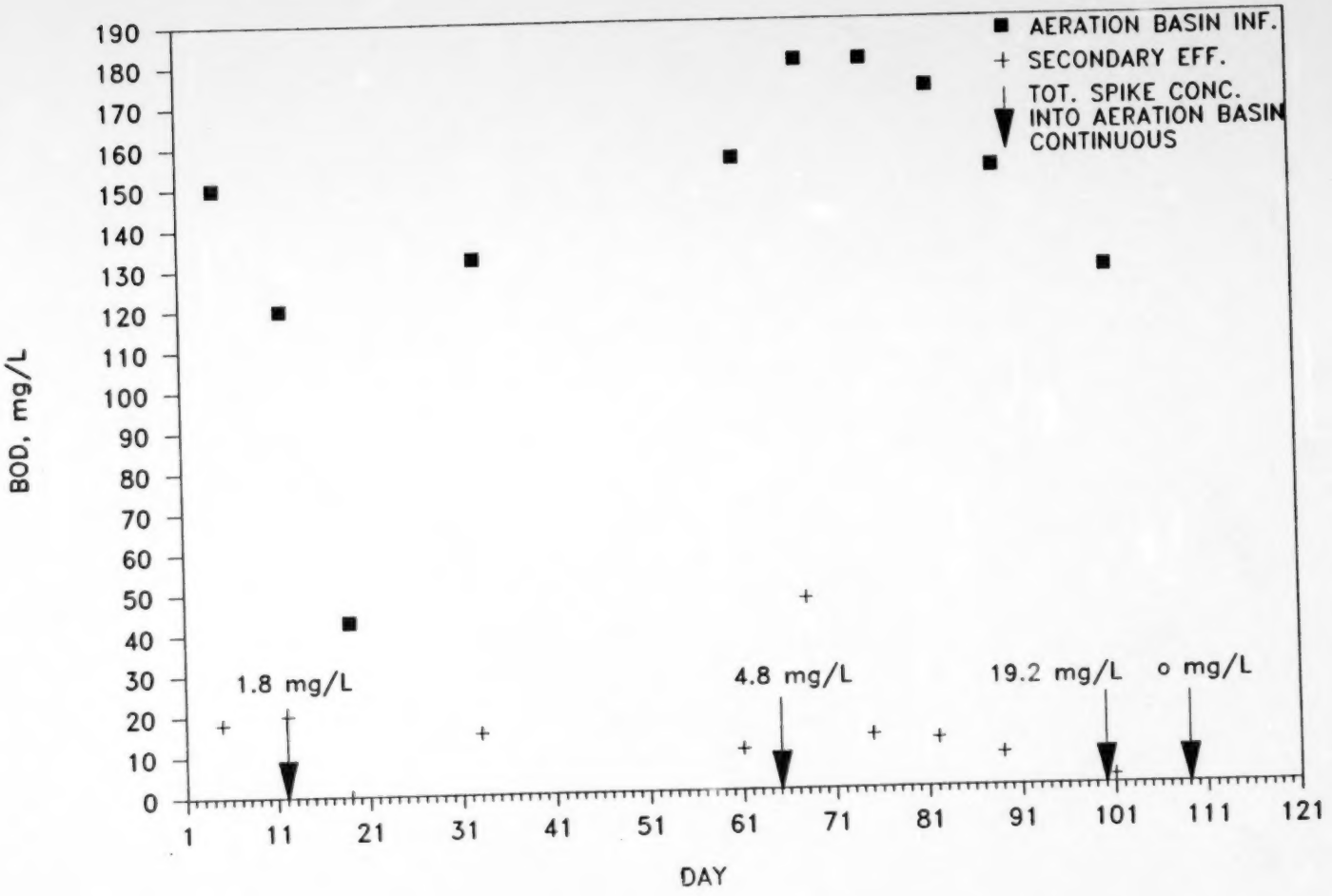


FIGURE 6.4, ACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT BOD

TABLE 6.4, COD FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			CONCENTRATION OF 28 SPIKED RCRA COMPOUNDS AND TEST PERIOD				
			BASELINE	TOTAL SPIKE* 1.8 mg/L	TOTAL SPIKE* 4.8 mg/L	TOTAL SPIKE*, ** 19.2 mg/L	TOTAL SPIKE 0 mg/L
			DAY 1 TO 11	DAY 12 TO 66	DAY 67 TO 99	DAY 100 TO 108	DAY 109 TO 122
COD (mg/L)	ABI.	AVG.	513.7	411.5	460.6	456.0	479.2
		S.D.	44.3	115.4	120.5	38.8	90.5
		#	3/3	23/23	14/15	3/3	5/5
	SEC. EFF.	AVG.	90.7	69.9	63.5	74.6	78.4
		S.D.	10.2	26.7	22.4	26.2	12.3
		#	3/3	23/23	11/15	3/3	5/5
% REDUCTION BY SEC.			82.3	83.0	86.2	83.6	83.6

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES INCLUDED/NUMBER OF SAMPLES

ABI.: AERATION BASIN INFLUENT
SEC. EFF.: SECONDARY EFFLUENT

TABLE 6.5, AMMONIA FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			CONCENTRATION OF 28 SPIKED RCRA COMPOUNDS AND TEST PERIOD						
			BASELINE	TOTAL SPIKE* 1.8 mg/L	TOTAL SPIKE* 4.8 mg/L	TOTAL SPIKE*, ** 19.2 mg/L	TOTAL SPIKE 0 mg/L	TOTAL SPIKE 0 mg/L	TOTAL SPIKE 0 mg/L
			DAY 1 TO 11	DAY 12 TO 66	DAY 67 TO 99	DAY 100 TO 108	DAY 109 TO 122	DAY 109 TO 111	DAY 112 TO 122
NH_3-N (mg/L AS N)	ABI.	AVG.	30.8	18.6	21.2	25.0	22.4	21.4	23.1
		S.D.	9.1	7.8	5.9	4.3	4.1	4.0	4.0
		#	3/3	23/23	17/17	5/6	5/5	2/2	3/3
	SEC. EFF.	AVG.	0.5	0.6	0.4	6.6	5.3	12.7	0.4
		S.D.	0.4	0.6	0.2	3.3	6.0	0.8	0.2
		#	3/3	23/23	17/17	5/6	5/5	2/2	3/3
	% REDUCTION BY SEC.		98.5	97.0	98.2	73.5	76.2	40.7	98.1
	ML	AVG.	1.1	1.4	1.5	7.9	6.0	13.3	1.2
		S.D.	0.4	0.4	0.5	3.7	6.0	0.8	0.2
		#	3/3	21/23	16/17	5/6	5/5	2/2	3/3

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES INCLUDED/NUMBER OF SAMPLES

ABI. AERATION BASIN INFLUENT
SEC. EFF.: SECONDARY EFFLUENT
ML: MIXED LIQUOR

DAY 1 WAS JANUARY 1, 1988

TABLE 6.6, PREDICTED AMMONIA REDUCTION FOR ACCLIMATED CONDITIONS

REDUCTION AND AND PREDICTED VALUES		BASELINE	TOTAL SPIKE* 1.8 mg/L	TOTAL SPIKE* 4.5 mg/L	TOTAL SPIKE*, ** 19.2 mg/L	TOTAL SPIKE 0 mg/L
		DAY 1 TO 11	DAY 12 TO 66	DAY 67 TO 99	DAY 100 TO 108	DAY 109 TO 122
NH_4-N (mg/L AS N)	A REDUCTION BY SEC.	30.4	17.7	20.8	18.4	17.1
ALKALINITY (mg/L AS CaCO3)	B REDUCTION BY SEC.	188.8	149.2	154.9	124.1	169.1
PREDICTED AMMONIA REDUCTION C C = B/7.14		26.4	20.9	21.7	17.4	23.7
% DIFFERENCE D D = |A - C|/(C) x 100		14.8	15.3	4.0	5.6	32.4

SEC.: SECONDARY TREATMENT

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT

**: CALCULATED

DAY 1 WAS JANUARY 1, 1988

TABLE 6.7, NITRATE FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			BASELINE DAY 1 TO 11	TOTAL SPIKE* 1.8 mg/L DAY 12 TO 66	TOTAL SPIKE* 4.8 mg/L DAY 67 TO 99	TOTAL SPIKE*,** 19.2 mg/L DAY 100 TO 108	TOTAL SPIKE 0 mg/L DAY 109 TO 122
NITRATE (mg/L AS N)	ABI.	AVG.	0.2	0.3	0.2	0.1	0
		S.D.	0	0.2	0.1	0.1	0
		#	3/3	19/23	17/17	5/6	5/5
	MIXED LIQUOR	AVG.	23.2	19.2	16.7	10.9	12.3
		S.D.	7.5	5.8	6	1.1	5.9
		#	3/3	21/23	16/17	5/6	5/5
	SEC. EFF.	AVG.	27.7	23.1	20.8	14.3	15.7
		S.D.	10.2	7.3	5.2	0.6	6.1
		#	3/3	22/23	17/17	5/6	5/5
	INCREASE BY SEC.		27.5	22.8	20.7	14.3	15.7
	" FROM ML TO SEC.		4.6	4	4.1	3.4	3.4

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES USED/NUMBER OF SAMPLES

ABI.: AERATION BASIN INFLUENT
SEC. EFF.: SECONDARY EFFLUENT
ML: MIXED LIQUOR SUSPENDED SOLIDS

DAY 1 WAS JANUARY 1, 1988

TABLE 6.8, TKN FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			BASELINE DAY 1 TO 11	TOTAL SPIKE* 1.8 mg/L DAY 12 TO 66	TOTAL SPIKE* 4.8 mg/L DAY 67 TO 99	TOTAL SPIKE*,** 19.2 mg/L DAY 100 TO 108	TOTAL SPIKE 0 mg/L DAY 109 TO 122
TKN (mg/L AS N)	ABI.	AVG.	41.6	30.6	30.6	33.5	31.6
		S.D.	9.7	8.5	7.4	5.9	3.9
		#	3/3	21/23	17/17	5/6	5/5
	SEC. EFF.	AVG.	3.3	2.8	2.9	7.8	7.7
		S.D.	0.6	0.9	0.8	3.0	5.4
		#	3/3	23/23	17/17	5/6	5/5
	% REDUCTION BY SEC.		92.1	90.8	90.5	76.6	75.8
	MIXED LIQUOR	AVG.	141.0	138.4	152.5	146.1	160.4
		S.D.	16.9	51.3	26.7	31.8	20.4
		#	3/3	20/21	16/17	5/6	5/5

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES USED/NUMBER OF SAMPLES

ABI.: AERATION BASIN INFLUENT
SEC. EFF.: SECONDARY EFFLUENT

DAY 1 WAS JANUARY 1, 1988

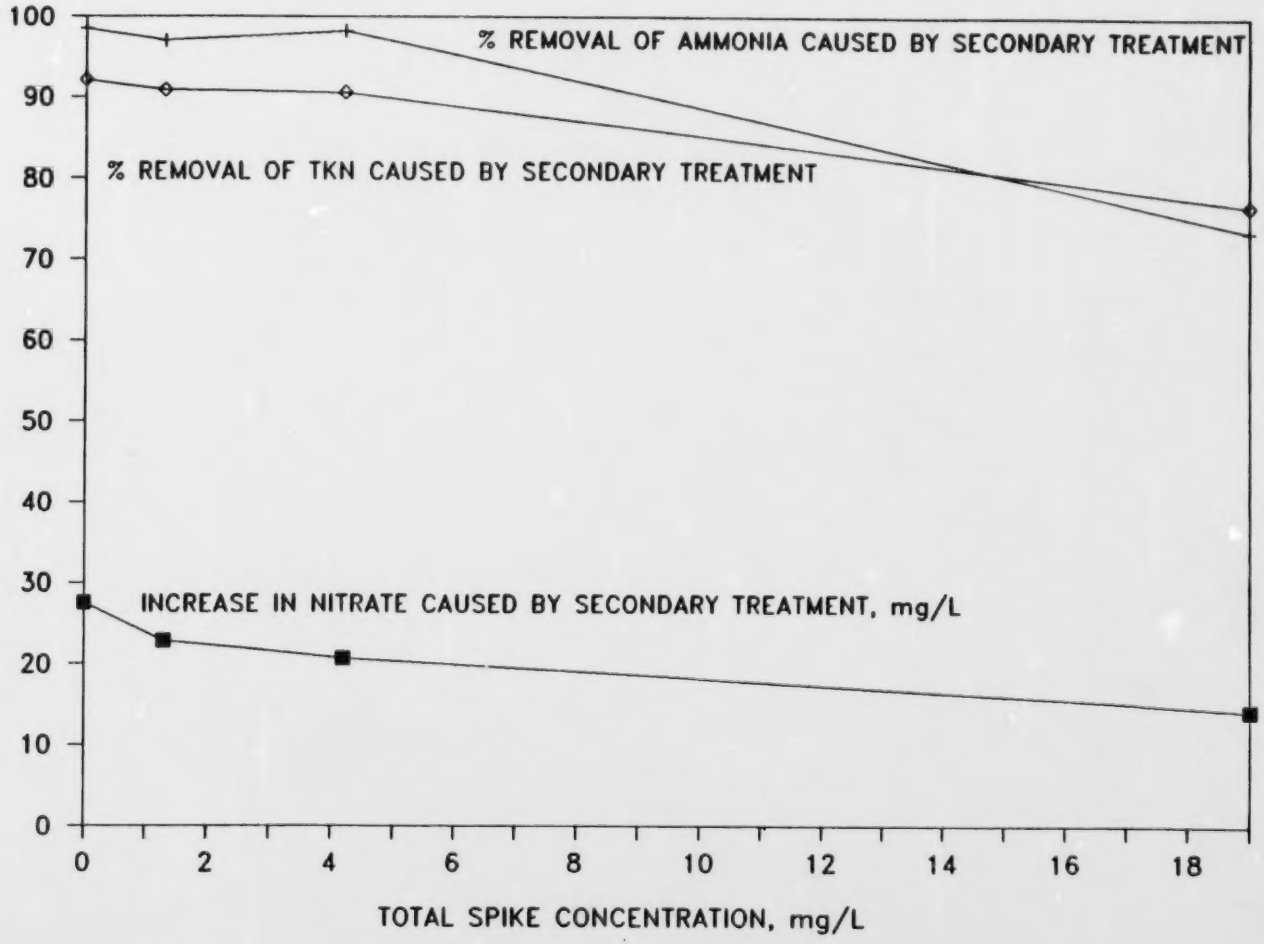


FIGURE 6.5, ACCLIMATED CONDITIONS, AMMONIA, TKN, NITRATE VS. CONCENTRATION OF SPIKE

TABLE 6.9, TOTAL PHOSPHORUS FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			BASELINE DAY 1 TO 11	TOTAL SPIKE* 1.8 mg/L DAY 12 TO 66	TOTAL SPIKE* 4.8 mg/L DAY 67 TO 99	TOTAL SPIKE*,** 19.2 mg/L DAY 100 TO 108	TOTAL SPIKE 0 mg/L DAY 109 TO 122
TP (mg/L AS P)	ABI.	AVG.	5.9	4.8	4.7	4.1	4.5
		S.D.	0.7	1.5	0.9	1.0	0.4
		#	3/3	23/23	17/17	6/6	5/5
	SEC. EFF.	AVG.	2.8	2.1	2.1	2.1	2.3
		S.D.	0.3	0.4	0.2	0.3	0.3
		#	3/3	23/23	17/17	6/6	5/5
	% REDUCTION BY SEC.		52.7	57.4	55.3	49.1	49.6

*: CONCENTRATION INTO AERATION BASIN, DILUTED PRIMARY EFFLUENT
**: CALCULATED

AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES INCLUDED/NUMBER OF SAMPLES

ABI.: AERATION BASIN INFLUENT
SEC. EFF.: SECONDARY EFFLUENT

DAY 1 WAS JANUARY 1, 1988

TABLE 6.10, PROCESS PARAMETERS FOR UNACCLIMATED CONDITIONS, DAY 1 TO 38

PROCESS PARAMETERS		SAMPLE ID AND % REDUCTION			
		ABI.	SEC. EFF.	MIXED LIQUOR	% REDUCTION BY SEC.
COD (mg/L)	AVG.	432.2	61.4		85.8
	S.D.	162.2	28.5		
	#	14/14	14/14		
AMMONIA (mg/L AS N)	AVG.	21.8	0.4	1.3	98.0
	S.D.	4.7	0.3	0.5	
	#	14/14	14/14	12/14	
NITRATE (mg/L AS N)	AVG.	0.4	25.1	19.7	24.67 *
	S.D.	0.5	8.6	6.2	
	#	13/14	14/14	12/14	
TKN (mg/L AS N)	AVG.	32.1	2.9	143.0	91.0
	S.D.	11.5	1.1	47.1	
	#	14/14	14/14	13/14	
TP (mg/L AS P)	AVG.	4.7	2.4		49.6
	S.D.	1.6	0.5		
	#	14/14	14/14		

ABI.: AERATION BASIN INFLUENT
AVG: AVERAGE
ID: IDENTIFICATION
S.D.: STANDARD DEVIATION
SEC. EFF.: SECONDARY EFFLUENT
#: NUMBER OF SAMPLES INCLUDED/NUMBER OF SAMPLES
*: INCREASE IN NITRATE, mg/L

DAY 1 WAS JANUARY 1, 1988

day 38, direct comparison of spiked and non-spiked conditions could not be made.

The average ammonia, nitrate and TKN values for the control system (day 1 to 38, Table 6.10), the baseline data for the spiked system before spiking (day 1 to 11, Table 6.8), the test period with a spike concentration of 1.8 mg/L (day 12 to 66 Table 6.8) and the test period with a spike concentration of 4.8 mg/L (day 67 to 99 Table 6.8) are similar. However, at the spike concentration of 19.2 mg/L a significant difference from the other periods resulted. COD reduction was similar for all of the test periods. A statistical regression analysis was attempted to verify the above results. However, because of the high degree of scatter, typical of a larger unit using actual wastewater, the results were of little value.

6.1.4 Conclusion

Nitrification was significantly inhibited at a total spike concentration of 19.2 mg/L. COD and phosphorus removal did not seem to be adversely affected by the spike even at the highest concentration tested, 19.2 mg/L.

6.2 INTERFERENCE CAUSED BY ORGANIC RCRA COMPOUNDS IN AN UNACCLIMATED NITRIFICATION PROCESS

An unacclimated biological wastewater treatment system is one in which the microorganisms are not adapted to foreign chemicals in the system. Shock loading can occur from chemicals that have been dumped by a generator. The performance of the process under shock loading conditions depends on the compounds, their concentration, the type of process, the plant's design and the control variables.

A pilot-scale extended aeration wastewater treatment system was used to assess the effect of the 28 RCRA compounds on the process parameters in an unacclimated wastewater treatment system when the system was shock loaded with these compounds. This system is described in Section 4.1. The average total spike concentration (total concentration of 28 compounds) was 1.3 mg/L for the three shock loadings.

6.2.1 Control and Operating Variables for the Unacclimated System

Table 6.11 and 6.12 show the operating and control variables for the system during the baseline period (day 1 to 38), the project period (day 1 to 63) and each toxic loading event. An event lasted two days. Samples were collected every four hours for the entire period, however, the compounds were spiked into the system during the first day only.

TABLE 6.11, OPERATING VARIABLES FOR UNACCLIMATED CONDITIONS

PROCESS PARAMETER		BASELINE PERIOD DAY 1 TO 38	PROJECT PERIOD DAY 1 TO 63	CONCENTRATION OF 28 TOTAL SPIKED RCRA COMPOUNDS, 1.3 mg/L EVENT 1 DAY 39 TO 40	EVENT 2 DAY 48 TO 49	EVENT 3 DAY 61 TO 62
SRT (DAYS)	AVG.	21	21	21	22	22
	S.D.	3	3			
	#	28/38	49/63	1/2	2/2	2/2
FLOW (L/MIN.)	AVG.	3.8	3.8	3.8	3.6	3.8
	S.D.	0.4	0.4			
	#	38/38	63/63	2/2	2/2	2/2
D.O. (mg/L O_2)	AVG.	6.2	6.0	6.7	5.8	3.2
	S.D.	1.3	1.3			
	#	38/38	63/63	2/2	2/2	2/2
MLTSS (mg/L)	AVG.	2495	2596	2625	2535	3400
	S.D.	550	482			
	#	37/38	62/63	2/2	2/2	2/2
MLVSS (mg/L)	AVG.	1890	1876	1785	1735	2440
	S.D.	442	428			
	#	38/38	63/63	2/2	2/2	2/2

AVG.: AVERAGE
MLTSS: MIXED LIQUOR TOTAL SUSPENDED SOLOIDS
MLVSS: MIXED LIQUOR VOLATILE SUSPENDED SOLIDS
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLE INCLUDED/NUMBER OF SAMPLES

DAY 1 WAS JANUARY 1, 1988

TABLE 6.12. CONTROL VARIABLES FOR UNACCLIMATED CONDITIONS

PROCESS PARAMETER		BASELINE PERIOD DAY 1 TO 38	PROJECT PERIOD DAY 1 TO 63	CONCENTRATION OF 28 TOTAL SPIKED RCRA COMPOUNDS, 1.3 mg/L EVENT 1 DAY 39 TO 40	EVENT 2 DAY 48 TO 49	EVENT 3 DAY 61 TO 62
pH ABI.	AVG.	7.7	7.7	7.9	7.8	7.6
	S.D.	0.2	0.3			
	#	38/38	63/63	2/2	2/2	2/2
pH SECONDARY EFFLUENT	AVG.	7.4	7.4	7.7	7.5	7.3
	S.D.	0.4	0.3			
	#	38/38	63/63	2/2	2/2	2/2
ALKALINITY (mg/L AS $CaCO_3$) ABI.	AVG.	239.4	240.7	264.0	256.0	216.0
	S.D.	48.8	42.9			
	#	38/38	63/63	2/2	2/2	2/2
ALKALINITY (mg/L AS $CaCO_3$) SECONDARY EFFLUENT	AVG.	77.9	83.6	82.0	101.0	96.0
	S.D.	36.9	31.2			
	#	38/38	63/63	2/2	2/2	2/2
TSS (mg/L) ABI.	AVG.	142.0	139.0	105.0	162.0	151.0
	S.D.	80.9	68.6			
	#	37/38	62/63	2/2	2/2	2/2
TSS (mg/L) SECONDARY EFFLUENT	AVG.	17	15	9	14	17
	S.D.	11.7	10.1			
	#	37/38	62/63	2/2	2/2	2/2

ABI.: AERATION BASIN INFLUENT
AVG.: AVERAGE
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLE INCLUDED/NUMBER OF SAMPLES

DAY 1 WAS JANUARY 1, 1988

For events 1 and 2, the SRTs, flows, MLSS, D.O.s, pHs, and alkalinities were similar. The MLSS, D.O. and alkalinity for event 3 varied slightly from the average, probably because of the varying sewage characteristics and operating conditions. All control parameters were within 15% of each other, except the D.O. during Event 3.

6.2.2 Interference Caused by Shock Loading of Organic RCRA Compounds

Figures 6.6, 6.7, 6.8 and 6.9 show effects of toxic shock loadings on the process parameters COD, ammonia, nitrate and BOD respectively, for the entire project period. For all four variables no interference appears to have occurred. A comparison of Table 6.10 (process parameters for day 1 to 38 before spiking) and Table 6.13 (day 1 to 63, entire project period) shows no significant differences in the average values.

6.3 REMOVAL OF ORGANIC RCRA COMPOUNDS BY AN ACCLIMATED EXTENDED AERATION WASTEWATER TREATMENT SYSTEM

Twenty-eight organic RCRA compounds were continuously spiked into a pilot-scale extended aeration wastewater treatment plant to assess their treatability and fate. Composite samples of aeration basin influent, secondary clarifier effluent and recycled activated sludge were collected three times for analysis of the 28 RCRA compounds (see section 4.2).

Tables 6.14, 6.15 and 6.16 show the results from the three sampling events. Table 6.17 is a summary of the results from all three events.

Some of the compounds were partially removed from the waste stream before reaching the aeration basin. The more volatile compounds could have been transferred to the atmosphere during storage or while in the primary clarifier. Some of the compounds could also have been partially removed by partitioning to the primary sludge. Analytical error is another probable cause of variability in concentrations of organics into the aeration basin.

Twenty-five compounds were removed to below detectable limits. As noted on Table 6.17, acetone was analyzed for but excluded from the summary table because the analyses were in error. Furfural was excluded as it was not found in the primary influent, even though it was part of the spike mixture. Methylene chloride was also excluded as it was used as a preservative in sludge samples.

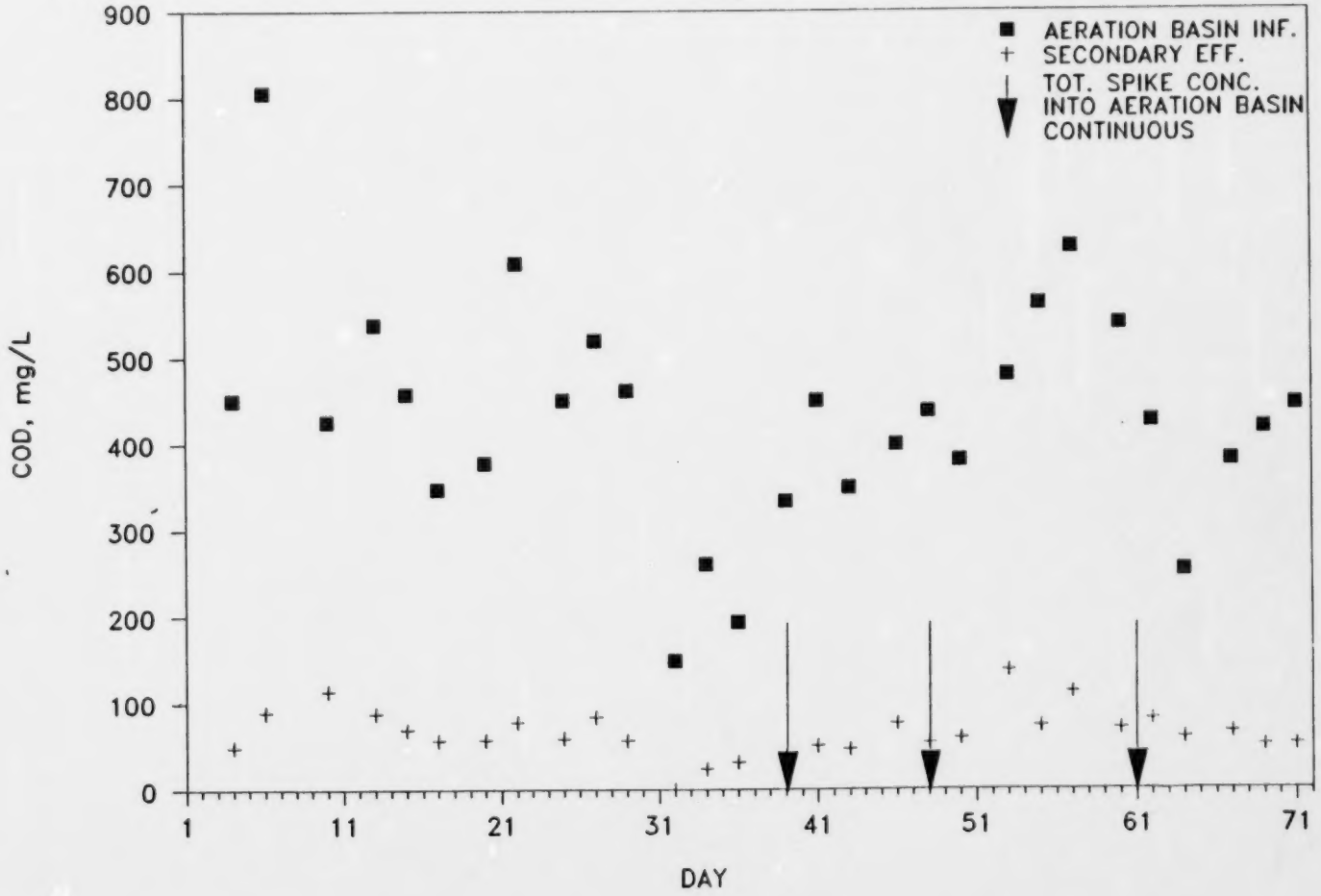


FIGURE 6.6. UNACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT COD

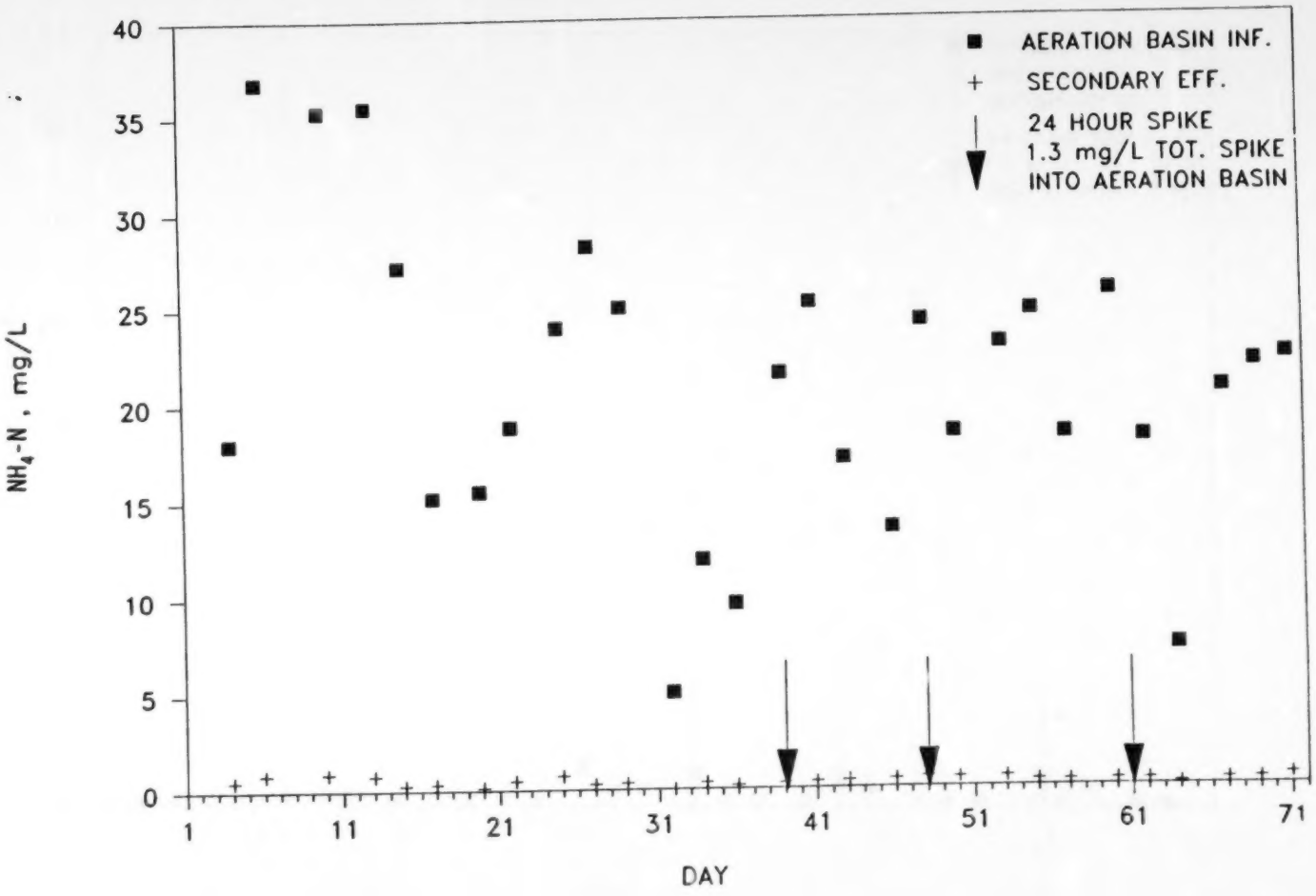


FIGURE 6.7. UNACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT AMMONIA

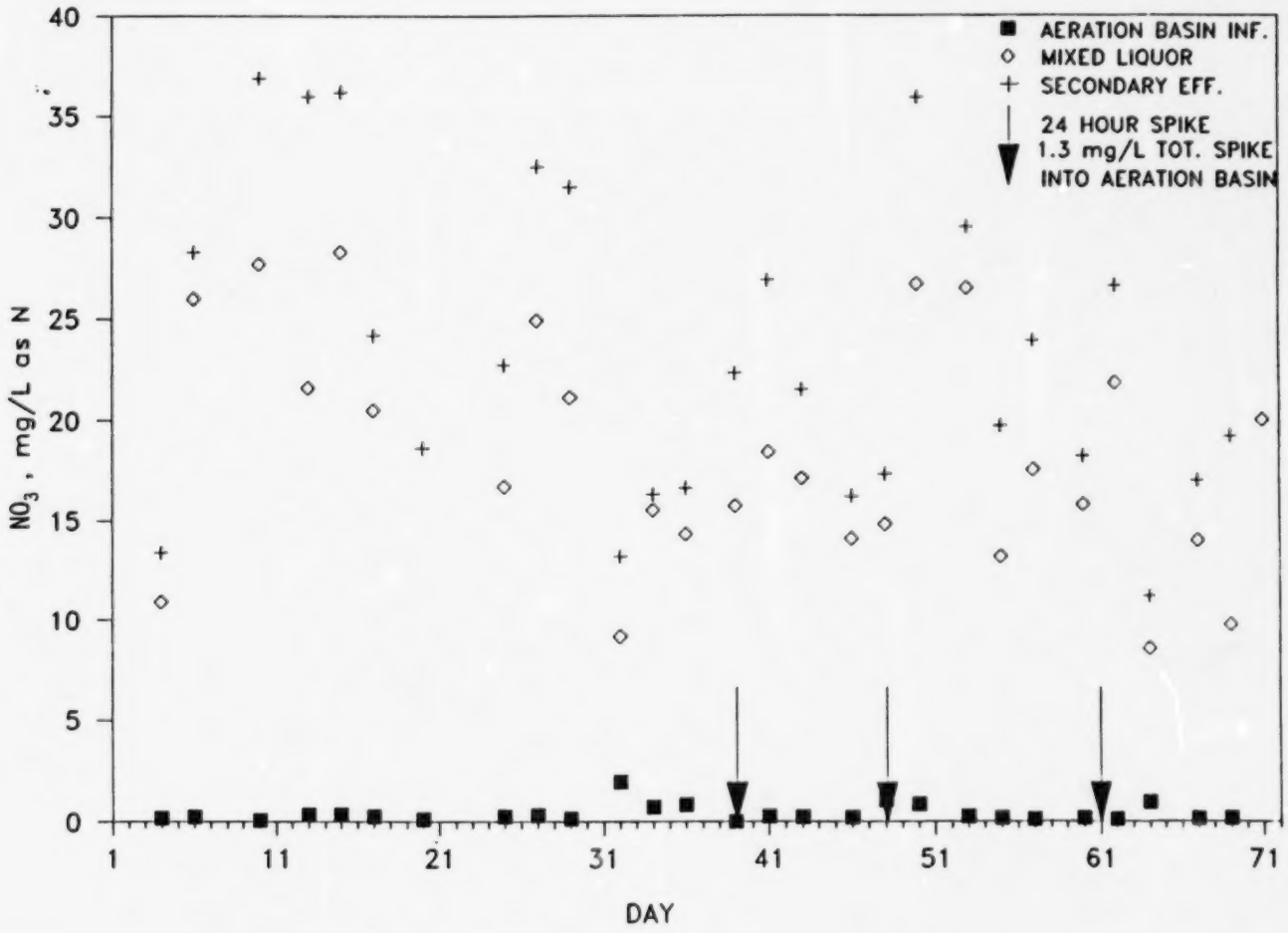


FIGURE 6.8. UNACCLIMATED CONDITIONS, EFFLUENT, INFLUENT AND MIXED LIQUOR NITRATE

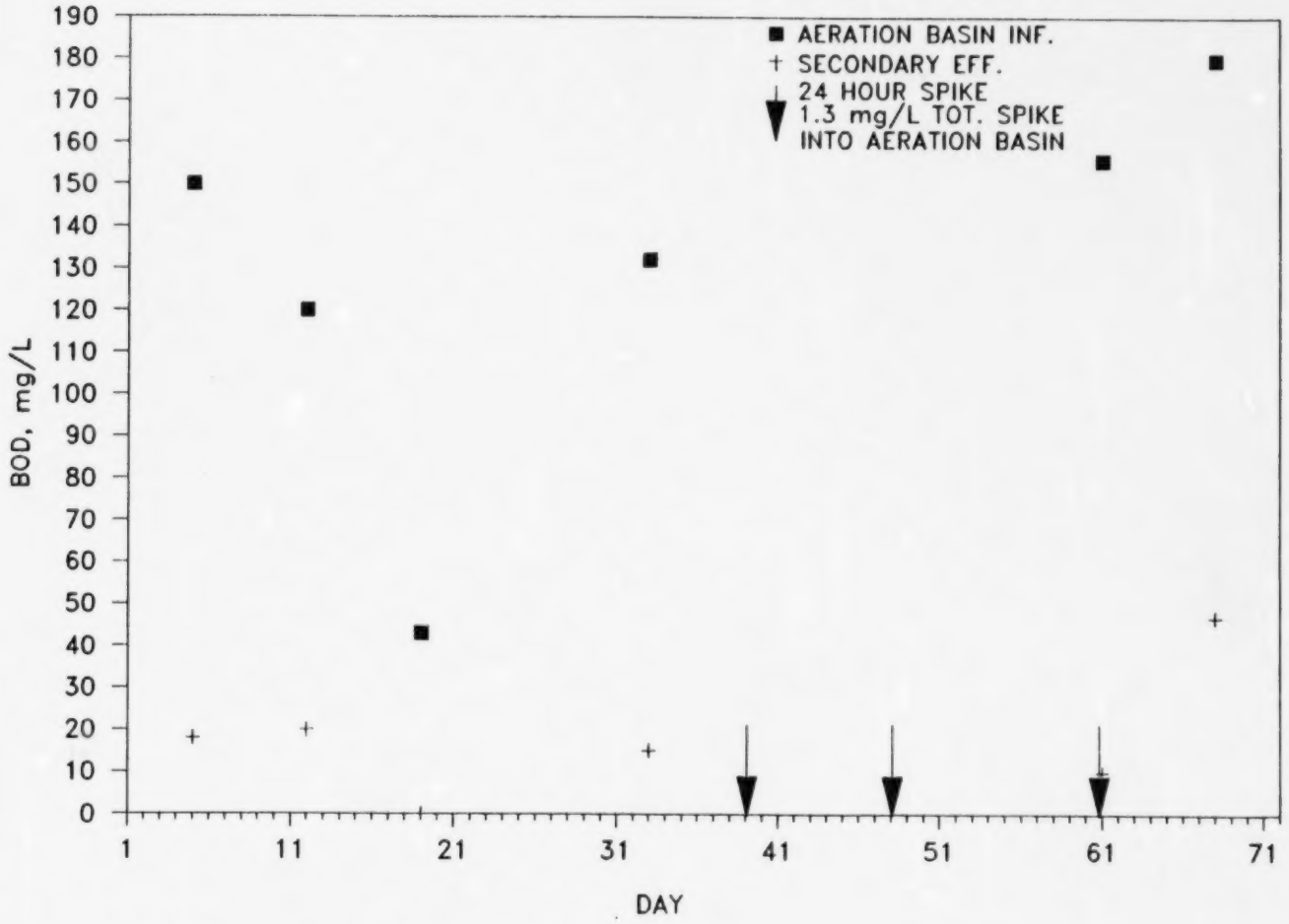


FIGURE 6.9, UNACCLIMATED CONDITIONS, INFLUENT AND EFFLUENT BOD

TABLE 6.13, PROCESS PARAMETERS FOR UNACCLIMATED CONDITIONS FOR DAY 1 TO 63

PROCESS PARAMETERS		SAMPLE ID AND % REDUCTION			
		ABI.	SEC. EFF.	MIXED LIQUOR	% REDUCTION BY SEC.
COD (mg/L)	AVG.	441.5	66.4		85.0
	S.D.	134.9	29.0		
	#	25/25	25/25		
AMMONIA (mg/L AS N)	AVG.	21.4	0.4	1.2	98.0
	S.D.	7.7	0.2	0.4	
	#	25/25	25/25	23/25	
NITRATE (mg/L AS N)	AVG.	0.4	24.4	19.1	23.93 *
	S.D.	0.4	7.5	5.5	
	#	24/25	24/25	23/25	
TKN (mg/L AS N)	AVG.	31.8	2.7	150.9	91.5
	S.D.	9.3	0.9	37.0	
	#	25/25	25/25	24/25	
TP (mg/L AS P)	AVG.	4.9	2.2		56.0
	S.D.	1.4	0.5		
	#	25/25	25/25		

ABI.: AERATION BASIN INFLUENT
AVG: AVERAGE
ID: IDENTIFICATION
S.D.: STANDARD DEVIATION
SEC. EFF.: SECONDARY EFFLUENT
#: NUMBER OF SAMPLES INCLUDED/NUMBER OF SAMPLES
*: INCREASE IN NITRATE

DAY 1 WAS JANUARY 1, 1988

TABLE 6.14, SAMPLING EVENT 1 FOR ACCLIMATED CONDITIONS

COMPOUND	ACCLIMATED CONDITONS ug/L			REDUCTION	
	ABI.	SECEFF.	WAS	(1) % REDSEC.	(2) % REDWAS.
Acetone	N	35 B	91 B	NF, I	NF,I
Cyclohexanone	210	N	N	100	0
Furfural	N	N	N	NF	NF
Methy ethyl Ketone	130	N	54	100	0
Methyl isobutyl ketone	120	N	12	100	0
Tetrahydrofuran	130	N	N	100	0
Carbon tetrachloride	79	N	N	100	0
Chlorobenzene	190	N	15	100	0
Chloroform	100	N	20	100	0
1,2-Dichloroethane	110	140	N	I	0
1,2-Dichloropropane	99	N	N	100	0
Tetrachloroethylene	73	N	N	100	0
Trichloroethylene	69	N	N	100	0
1,1,1-Trichloroethane	100	N	N	100	0
1,1,2-Trichloroethane	91	5	N	95	0
Ethylbenzene	75	N	17	100	0
Toluene	130	N	43	100	0
o-xylene	150	N	19	100	0
Bis(2-ethylhexyl)phthalate	40	N	14	100	0
Butyl benzyl phthalate	N	N	N	NF	NF
1,4-Dichlorobenzene	N	N	N	NF	NF
2,4-Dimethylphenol	10	N	N	100	0
2,4-Dinitrophenol	40	N	N	100	0
Naphthalene	64	N	N	100	0
Nitrobenzene	35	N	N	100	0
4-Nitrophenol	N	N	N	NF	NF
Phenol	120	N	N	100	0

B: COMPOUND FOUND IN BLANK

I: INFLUENT CONCENTRATION WAS LESS THAN EFFLUENT CONCENTRATION

N: NONE DETECTED

NF: COMPOUND NOT FOUND IN ABI.

(1): (ABI. - SECEFF.)/(ABI.)*100

(2): (48 L/DAY)(WAS)/(5270 L/DAY)(ABI.)*100

ABI.: AERATION BASIN INFLUENT

SECEFF.: SECONDARY EFFLUENT

WAS: WASTE ACTIVATED SLUDGE

% REDSEC.: % REDUCTION OF COMPOUND CAUSED BY SECONDARY TREATMENT

% REDWAS.: % OF COMPOUND REMOVED BY WAS

TABLE 6.15, SAMPLING EVENT 2 FOR ACCLIMATED CONDITIONS

COMPOUND	ACCLIMATED CONDITIONS ug/L				REDUCTION	
	ABI.	SECEFF.	SECEFF. DUP.	WAS	(1) % REDSEC.	(2) % REDWAS.
Acetone	N	N	N	390	NF	1
Cyclohexanone	N	N	N	N	NF	NF
Furfural	N	N	N	N	NF	NF
Methy ethyl Ketone	150	N	N	N	100	0
Methyl isobutyl ketone	N	N	N	N	NF	NF
Tetrahydrofuran	N	N	N	N	NF	NF
Carbon tetrachloride	64	N	N	N	100	0
Chlorobenzene	110	N	N	N	100	0
Chloroform	81	N	N	N	100	0
1,2-Dichloroethane	93	N	N	N	100	0
1,2-Dichloropropane	67	N	N	N	100	0
Tetrachloroethylene	64	N	N	N	100	0
Trichloroethylene	62	N	N	N	100	0
1,1,1-Trichloroethane	70	N	N	N	100	0
1,1,2-Trichloroethane	74	N	N	N	100	0
Ethylbenzene	65	N	N	N	100	0
Toluene	110	N	N	N	100	0
o-xylene	21	N	N	N	100	0
Bis(2-ethylhexyl)phthalate	40	6	N	13	85	0
Butyl benzyl phthalate	13	N	N	N	100	0
1,4-Dichlorobenzene	N	N	N	N	NF	NF
2,4-Dimethylphenol	N	N	N	N	NF	NF
2,4-Dinitrophenol	N	N	N	N	NF	NF
Naphthalene	77	N	N	N	100	0
Nitrobenzene	N	N	N	N	NF	NF
4-Nitrophenol	N	N	N	N	NF	NF
Phenol	N	N	N	N	NF	NF

I: INFLUENT CONCENTRATION WAS LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NF: COMPOUND NOT FOUND IN ABI.

(1): (ABI. - SECEFF.)/(ABI.)*100
(2): (48 L/DAY)(WAS)/(5270 L/DAY)(ABI.)*100

ABI.: AERATION BASIN INFLUENT
DUP.: DUPLICATE SAMPLE
SECEFF.: SECONDARY EFFLUENT
WAS: WASTE ACTIVATED SLUDGE

% REDSEC.: % REDUCTION OF COMPOUND CAUSED BY SECONDARY TREATMENT
% REDWAS.: % OF COMPOUND REMOVED BY WAS

TABLE 6.16, SAMPLING EVENT 3 FOR ACCLIMATED CONDITIONS

COMPOUND	ACCLIMATED CONDITIONS ug/L				REDUCTION	
	ABI.	SECEFF.	DUP.	WAS	(1) % REDSEC.	(2) % REDWAS.
Acetone	1900	N	6 B	N	100	0
Cyclohexanone	N	N	N	N	NF	NF
Furfural	N	N	N	N	NF	NF
Methy ethyl Ketone	148	N	N	N	100	0
Methyl isobutyl ketone	N	N	N	N	NF	NF
Tetrahydrofuran	63	N	N	N	100	0
Carbon tetrachloride	70	N	N	N	100	0
Chlorobenzene	100	N	N	N	100	0
Chloroform	90	N	N	N	100	0
1,2-Dichloroethane	96	N	N	N	100	0
1,2-Dichloropropane	74	N	N	N	100	0
Tetrachloroethylene	66	N	N	N	100	0
Trichloroethylene	70	N	N	N	100	0
1,1,1-Trichloroethane	77	N	N	N	100	0
1,1,2-Trichloroethane	72	N	N	N	100	0
Ethylbenzene	95	N	N	N	100	0
Toluene	170	N	N	N	100	0
o-xylene	42	N	N	N	100	0
Bis(2-ethylhexyl)phthalate	45	9	N	60	80	1
Butyl benzyl phthalate	7	N	N	N	100	0
1,4-Dichlorobenzene	42	N	N	N	100	0
2,4-Dimethylphenol	N	N	N	N	NF	NF
2,4-Dinitrophenol	N	N	N	N	NF	NF
Naphthalene	67	N	N	N	100	0
Nitrobenzene	68	N	N	N	100	0
4-Nitrophenol	32	N	N	N	100	0
Phenol	180	N	N	N	100	0

B: COMPOUND FOUND IN BLANK
N: NONE DETECTED
NF: COMPOUND NOT FOUND IN ABI.

(1): (ABI. - SECEFF.)/(ABI.)*100
(2): (48 L/DAY)(WAS)/(5270 L/DAY)(ABI.)*100

ABI.: AERATION BASIN INFLUENT
DUP.: DUPLICATE SAMPLE
SECEFF.: SECONDARY EFFLUENT
WAS: WASTE ACTIVATED SLUDGE

% REDSEC.: % REDUCTION OF COMPOUND CAUSED BY SECONDARY TREATMENT
% REDWAS.: % OF COMPOUND REMOVED BY WAS

TABLE 6.17, SUMMARY OF SAMPLING EVENTS FOR ACCLIMATED CONDITIONS

COMPOUND	EVENT 1		EVENT 2		EVENT 3		AVG. ABI. (ug/L)	AVG. % REDSEC	#
	ABI.	% REDSEC	ABI.	% REDSEC	ABI.	% REDSEC			
Cyclohexanone	210	100	N	NF	N	NF	210	100	1
Methy ethyl Ketone	130	100	150	100	148	100	143	100	3
Methyl isobutyl ketone	120	100	N	NF	N	NF	120	100	1
Tetrah furan	130	100	N	NF	63	100	97	100	2
Carbon tetrachloride	79	100	64	100	70	100	71	100	3
Chlorobenzene	190	100	110	100	100	100	133	100	3
Chloroform	100	100	81	100	90	100	90	100	3
1,2-Dichloroethane	110	I	93	100	96	100	95	100	2
1,2-Dichloropropane	99	100	67	100	74	100	80	100	3
Tetrachloroethylene	73	100	64	100	66	100	68	100	3
Trichloroethylene	69	100	62	100	70	100	67	100	3
1,1,1-Trichloroethane	100	100	70	100	77	100	82	100	3
1,1,2-Trichloroethane	91	95	74	100	72	100	79	100	3
Ethylbenzene	75	100	65	100	95	100	78	100	3
Toluene	130	100	110	100	170	100	137	100	3
o-xylene	150	100	21	100	42	100	71	100	3
Bis(2-ethylhexyl)phthalate	40	100	40	85	45	100	42	100	3
Butyl benzyl phthalate	N	NF	13	100	N	NF	13	100	1
1,4-Dichlorobenzene	N	NF	N	NF	42	100	42	100	1
2,4-Dimethylphenol	10	100	N	NF	N	NF	10	100	1
2,4-Dinitrophenol	40	100	N	NF	N	NF	40	100	1
Naphthalene	64	100	77	100	67	100	69	100	3
Nitrobenzene	35	100	N	NF	68	100	52	100	2
4-Nitrophenol	N	NF	N	NF	32	100	32	100	1
Phenol	120	100	N	NF	180	100	150	100	2

ABI.: CONCENTRATION INTO AERATION BASIN, ug/L
AVG.: AVERAGE
% REDSEC: PERCENT OF COMPOUND REDUCED BY SECONDARY TREATMENT
#: NUMBER OF SAMPLES WITH VALID VALUES, OUT OF 3

I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATIONS
N: NONE DETECTED
NF: COMPOUND NOT FOUND IN AERATION BASIN INFLUENT

NOTE: ACETONE, METHYLENE CHLORIDE AND FURFURAL WERE ANALYZED FOR BUT NOT FOUND IN FEED OR THE COMBOUND WAS FOUND IN THE BLANK

6.4 REMOVAL OF ORGANIC RCRA COMPOUNDS BY AN UNACCLIMATED EXTENDED AERATION WASTEWATER TREATMENT SYSTEM

Tables 6.18, 6.19 and 6.20 show the results of shock spiking to the treatment plant for each event. Table 6.21 is a summary of all three events. A direct comparison to the acclimated system is statistically not feasible because the spiking arrangements were not similar.

For this study acetone and furfural were excluded from the summary (Table 6.21) for the same reasons as in the acclimated study. However, butyl benzyl phthalate, 2,4-dinitrophenol, 2,4-dimethylphenol and 4-nitrophenol were also excluded because they were not found in the aeration basin influent.

Only four compounds had removals less than 95%. These compounds were 1,1,2-trichloroethane, bis(2-ethylhexyl) phthalate, toluene and nitrobenzene. As noted in Section 3.1.5, other researchers found similar results for bis(2-ethylhexyl)phthalate.

6.5 REMOVAL OF ORGANIC RCRA COMPOUNDS BY DUAL MEDIA EFFLUENT FILTRATION

The secondary effluent from both the acclimated and unacclimated nitrification systems were passed through dual media effluent filters for the first 62 days of the project. The secondary effluent from the conventional system (EPA Contract #68-03-4038, see Section 4.1) was passed through one of the filters after day 62. Eleven analyses were run for the organic RCRA compounds going into and coming out of the filter; three for the nitrification secondary effluent and the others for the conventional system.

The TSS and COD for each time period are listed in Table 6.22 and the results from all of the acclimated sample events in Table 6.23. Because the removal of the RCRA compounds by the filter for both the acclimated and unacclimated nitrification system were similar, only the acclimated system numbers have been reported.

The filters removed approximately 50% TSS for most operating conditions. The secondary effluent from the nitrification system had very low concentrations of RCRA compounds. Consequently the effectiveness of the filters could not be assessed for the first 62 days of the project. Higher concentrations of some of the compounds were present in the secondary effluent from the conventional system. The removal of these compounds by the filters (day 63 to 90) is summarized in Table 6.24. Because of the questionable quality of the analyses, Table 6.24 only reports data from duplicate samples that were within 30% of one another. Analyses of samples that did not have a duplicate were not included. The results from this table indicate that only acetone, tetrahydrofuran, tetrachloroethylene and phenol had significant removals by the

TABLE 6.18, SAMPLING EVENT 1 FOR UNACCLIMATED CONDITIONS

COMPOUND	UNACCLIMATED CONDITIONS ug/L			REDUCTION	
	ABI.	SECEFF.	WAS	(1) % REDSEC.	(2) % REDWAS.
Acetone	N	440 B	940 B	I	I
Cyclohexanone	180	N	N	100	0
Furfural	N	N	N	NF	NF
Methy ethyl Ketone	140	N	100	100	1
Methyl isobutyl ketone	71	N	100	100	1
Tetrahydrofuran	97	N	140	100	1
Carbon tetrachloride	36	N	53	100	1
Chlorobenzene	65	N	150	100	2
Chloroform	72	N	82	100	1
1,2-Dichloroethane	N	N	84	NF	I
1,2-Dichloropropane	50	N	74	100	1
Tetrachloroethylene	19	N	53	100	2
Trichloroethylene	27	N	50	100	2
1,1,1-Trichloroethane	64	N	73	100	1
1,1,2-Trichloroethane	61	N	72	100	1
Ethylbenzene	17	N	59	100	3
Toluene	57	19	100	67	2
o-xylene	48	N	120	100	2
Bis(2-ethylhexyl)phthalate	38	N	34	100	1
Butyl benzyl phthalate	N	N	N	NF	NF
1,4-Dichlorobenzene	28	N	N	100	0
2,4-Dimethylphenol	5	N	N	100	0
2,4-Dinitrophenol	N	N	N	NF	NF
Naphthalene	54	N	N	100	0
Nitrobenzene	76	19	9	75	0
4-Nitrophenol	N	N	N	NF	NF
Phenol	170	N	N	100	0

B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION WAS LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NF: COMPOUND NOT FOUND IN ABI.

(1): (ABI. - SECEFF.)/(ABI.)*100
(2): (48 L/DAY)(WAS)/(5429 L/DAY)(ABI.)*100

ABI.: AERATION BASIN INFLUENT
SECEFF.: SECONDARY EFFLUENT
WAS: WASTE ACTIVATED SLUDGE

% REDSEC.: % REDUCTION OF COMPOUND CAUSED BY SECONDARY TREATMENT
% REDWAS.: % OF COMPOUND REMOVED BY WAS

TABLE 6.19, SAMPLING EVENT 2 FOR UNACCLIMATED CONDITIONS

COMPOUND	UNACCLIMATED CONDITIONS ug/L				REDUCTION	
	ABI.	SECEFF.	SECEFF. DUP.	WAS	(1) % REDSEC.	(2) % REDWAS.
Acetone	2600 B	N	21 B	N	100	0
Cyclohexanone	N	N	N	N	NF	NF
Furfural	N	N	N	N	NF	NF
Methy ethyl Ketone	240	N	N	N	100	0
Methyl isobutyl ketone	N	N	N	N	NF	NF
Tetrahydrofuran	N	23	31	N	NF, I	NF
Carbon tetrachloride	N	N	N	N	NF	NF
Chlorobenzene	76	N	N	N	100	0
Chloroform	36	N	N	N	100	0
1,2-Dichloroethane	12	N	N	N	100	0
1,2-Dichloropropane	31	N	N	N	100	0
Tetrachloroethylene	36	N	N	N	100	0
Trichloroethylene	25	N	N	N	100	0
1,1,1-Trichloroethane	N	N	N	N	NF	NF
1,1,2-Trichloroethane	24	3	2	N	88	0
Ethylbenzene	77	1	1	20	99	0
Toluene	96	1	N	26	99	0
o-xylene	130	2	2	32	98	0
Bis(2-ethylhexyl)phthalate	22	4	11	42	82	2
Butyl benzyl phthalate	N	N	N	N	NF	NF
1,4-Dichlorobenzene	22	N	N	N	100	0
2,4-Dimethylphenol	N	N	4	N	NF	NF
2,4-Dinitrophenol	N	N	N	N	NF	NF
Naphthalene	50	N	N	N	100	0
Nitrobenzene	32	7	7	N	78	0
4-Nitrophenol	N	N	N	N	NF	NF
Phenol	130	N	N	N	100	0

B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION WAS LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NF: COMPOUND NOT FOUND IN ABI.

(1): (ABI. - SECEFF.)/(ABI.)*100
(2): (48 L/DAY)(WAS)/(5429 L/DAY)(ABI.)*100

ABI.: AERATION BASIN INFLUENT
DUP.: DUPLICATE
SECEFF.: SECONDARY EFFLUENT
WAS: WASTE ACTIVATED SLUDGE

% REDSEC.: % REDUCTION OF COMPOUND CAUSED BY SECONDARY TREATMENT
% REDWAS.: % OF COMPOUND REMOVED BY WAS

TABLE 6.20, SAMPLING EVENT 3 FOR UNACCLIMATED CONDITIONS

COMPOUND	UNACCLIMATED CONDITIONS ug/L				REDUCTION	
	ABI.	SECEFF.	SECEFF. DUP.	WAS	(1) % REDSEC.	(2) % REDWAS.
Acetone	1700 B	31 B	23 B	2300 B	98	1
Cyclohexanone	N	N	N	N	NF	NF
Furfural	N	N	N	N	NF	NF
Methy ethyl Ketone	330	N	6	N	100	0
Methyl isobutyl ketone	75	N	1	590	100	7
Tetrahydrofuran	N	N	N	N	NF	NF
Carbon tetrachloride	35	N	N	N	100	0
Chlorobenzene	73	N	N	N	100	0
Chloroform	66	N	N	91	100	1
1,2-Dichloroethane	N	N	2	N	NF	NF
1,2-Dichloropropane	40	N	N	N	100	0
Tetrachloroethylene	32	N	N	N	100	0
Trichloroethylene	46	N	N	N	100	0
1,1,1-Trichloroethane	50	N	N	N	100	0
1,1,2-Trichloroethane	42	4	5	N	90	0
Ethylbenzene	45	N	N	160	100	3
Toluene	120	N	N	270	100	2
o-xylene	66 B	N	1 B	280 B	100	4
Bis(2-ethylhexyl)phthalate	15	N	210	45	100	3
Butyl benzyl phthalate	N	N	230	N	NF	NF
1,4-Dichlorobenzene	24	N	71	N	100	0
2,4-Dimethylphenol	N	N	N	N	NF	NF
2,4-Dinitrophenol	N	N	N	N	NF	NF
Naphthalene	38	N	96	N	100	0
Nitrobenzene	36	7	N	N	81	0
4-Nitrophenol	N	N	N	N	NF	NF
Phenol	220	N	320	N	100	0

B: COMPOUND FOUND IN BLANK
N: NONE DETECTED
NF: COMPOUND NOT FOUND IN ABI.

(1): (ABI. - SECEFF.)/(ABI.)*100
(2): (48 L/DAY)(WAS)/(5429 L/DAY)(ABI.)*100

ABI.: AERATION BASIN INFLUENT
DUP.: DUPLICATE SAMPLE
SECEFF.: SECONDARY EFFLUENT
WAS: WASTE ACTIVATED SLUDGE

% REDSEC.: % REDUCTION OF COMPOUND CAUSED BY SECONDARY TREATMENT
% REDWAS.: % OF COMPOUND REMOVED BY WAS

TABLE 6.21, SUMMARY OF SAMPLING EVENTS FOR UNACCLIMATED CONDITIONS

COMPOUND	EVENT 1		EVENT 2		EVENT 3		AVG.		
	ABI.	% REDSEC	ABI.	% REDSEC	ABI.	% REDSEC	ABI. (ug/L)	AVG. % REDSEC	#
Cyclohexanone	180	100	N	NF	N	NF	180	100	1
Methy ethyl Ketone	140	100	240	100	330	100	237	100	3
Methyl isobutyl ketone	71	100	N	NF	75	100	73	100	2
Tetrahydrofuran	97	100	N	I	N	NF	97	100	1
Carbon tetrachloride	36	100	N	NF	35	100	36	100	2
Chlorobenzene	65	100	76	100	73	100	71	100	3
Chloroform	72	100	36	100	66	100	58	100	3
1,2-Dichloroethane	N	NF	12	100	N	NF	12	100	1
1,2-Dichloropropane	50	100	31	100	40	100	40	100	3
Tetrachloroethylene	19	100	36	100	32	100	29	100	3
Trichloroethylene	27	100	25	100	46	100	33	100	3
1,1,1-Trichloroethane	64	100	N	NF	50	100	57	100	2
1,1,2-Trichloroethane	61	100	24	88	42	90	42	93	3
Ethylbenzene	17	100	77	99	45	100	46	100	3
Toluene	57	67	96	99	120	100	91	89	3
o-xylene	48	100	130	98	66 B	100	81	99	3
Bis(2-ethylhexyl)phthalate	38	100	22	82	15	100	25	94	3
1,4-Dichlorobenzene	28	100	22	100	24	100	25	100	3
Naphthalene	54	100	50	100	38	100	47	100	3
Nitrobenzene	76	75	32	78	36	81	48	78	3
Phenol	170	100	130	100	220	100	173	100	3

% REDSEC: PERCENT OF COMPOUND REDUCED BY SECONDARY TREATMENT
#: NUMBER OF SAMPLES WITH VALID VALUES, OUT OF 3

ABI.: CONCENTRATION INTO AERATION BASIN, ug/L
AVG.: AVERAGE
B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NF: COMPOUND NOT FOUND IN AERATION BASIN INFLUENT

NOTE: ACETONE, FURFURAL, METHYLENE CHLORIDE, BUTYL BENZYL PHTHALATE, 2,4-DINTROPHENOL, 2,4-DIMETHYLPHENOL AND 4-NITROPHENOL WERE ANALYZED FOR BUT NOT FOUND IN FEED OR THE COMPOUND WAS FOUND IN THE BLANK

TABLE 6.22, TSS AND COD FOR EFFLUENT FILTERS FOR ACCLIMATED CONDITIONS

PROCESS PARAMETER AND SAMPLE ID			NITRIFICATION DAY 12 TO 66	CONVENTIONAL DAY 63 TO 90
TSS (mg/L)	FILIN.	AVG.	16	7
		S.D.	8	10
		#	54/55	26/28
	FILOUT.	AVG.	8	4
		S.D.	9	4
		#	54/55	22/28
	% REDUCTION BY FIL.		50	43
COD (mg/L)	FILIN.	AVG.	70	90
		S.D.	27	37
		#	23/23	6/8
	FILOUT.	AVG.	66	47
		S.D.	22	24
		#	18/21	12/12
	% REDUCTION BY FIL.		6	48

AVG.: AVERAGE
EFF.: EFFLUEN
FILIN.: INFLUENT TO FILTER
FILOUT.: EFFLUENT FROM FILTER
S.D.: STANDARD DEVIATION
#: NUMBER OF SAMPLES INCLUDED/NUMBER OF SAMPLES

TABLE 6.23, TOXIC FILTERS SAMPLING EVENTS FOR
ACCLIMATED CONDITIONS

COMPOUND	EVENT 1, DAY 39			EVENT 2, DAY 48					
	FILIN.	FILOUT.	% RED.	FILIN.	FILIN. D.	FILOUT.	FILOUT. D.	% RED.	% RED. D.
Acetone	36 B	5700 B	I	N	N	24	N	I	NFI
Cyclohexanone	N	N	NFI	N	N	N	N	NFI	NFI
Furfural	N	N	NFI	N	N	N	N	NFI	NFI
Methy ethyl Ketone	N	N	NFI	N	N	N	N	NFI	NFI
Methyl isobutyl ketone	N	N	NFI	N	N	N	N	NFI	NFI
Tetrahydrofuran	N	N	NFI	N	N	N	N	NFI	NFI
Carbon tetrachloride	N	N	NFI	N	N	N	N	NFI	NFI
Chlorobenzene	N	N	NFI	N	N	N	N	NFI	NFI
Chloroform	N	N	NFI	N	N	N	N	NFI	NFI
1,2-Dichloroethane	140	N	100	N	N	N	N	NFI	NFI
1,2-Dichloropropane	N	130000 B	NFI, I	N	N	N	N	NFI	NFI
Methylene chloride	4900 B	N	B	B	7	79	220	I	I
Tetrachloroethylene	N	N	NFI	N	N	N	N	NFI	NFI
Trichloroethylene	N	N	NFI	N	N	N	N	NFI	NFI
1,1,1-Trichloroethane	N	N	NFI	N	N	N	N	NFI	NFI
1,1,2-Trichloroethane	5	N	100	N	N	N	N	NFI	NFI
Ethylbenzene	N	N	NFI	N	N	N	N	NFI	NFI
Toluene	19	1400	I	N	N	N	N	NFI	NFI
o-xylene	N	N	NFI	N	N	N	N	NFI	NFI
Bis(2-ethylhexyl)phthalate	N	N	NFI	6	N	5	7	17	NFI, I
Butyl benzyl phthalate	N	N	NFI	N	N	N	N	NFI	NFI
1,4-Dichlorobenzene	N	N	NFI	N	N	N	N	NFI	NFI
2,4-Dimethylphenol	N	N	NFI	N	N	N	N	NFI	NFI
2,4-Dinitrophenol	N	N	NFI	N	N	N	N	NFI	NFI
Naphthalene	N	N	NFI	N	N	N	N	NFI	NFI
Nitrobenzene	19	N	ERR	N	N	N	N	NFI	NFI
4-Nitrophenol	N	N	NFI	N	N	N	N	NFI	NFI
Phenol	N	N	NFI	N	N	N	N	NFI	NFI

D.: DUPLICATE
FILIN: INFLUENT TO FILTER, ug/L
FILOUT: EFFLUENT FROM FILTER, ug/L
% RED.: REDUCTION OF COMPOUND CAUSED BY THE FILTER

B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NFI: COMPOUND NOT FOUND IN FILIN.

TABLE 6.23 (Continued)

COMPOUND	EVENT 3, DAY 61						EVENT 4, DAY 69					
	FILIN.	FILIN. D	FILOUT.	FILOUT. D	% RED.	% RED. D	FILIN.	FILIN. D	FILOUT.	FILOUT. D	% RED.	% RED. D
Acetone	N	6 B	6 B	N	100	I	N	N	N	5	NFI	I
Cyclohexanone	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Furfural	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Methy ethyl Ketone	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Methyl isobutyl ketone	N	N	N	N	NFI	NFI	380	160	320	620	16	I
Tetrahydrofuran	N	N	N	N	NFI	NFI	3	3	N	2	100	33.00
Carbon tetrachloride	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Chlorobenzene	N	N	N	N	NFI	NFI	31	36	23	27	26	25
Chloroform	N	N	N	N	NFI	NFI	94	82	73	87	22	I
1,2-Dichloroethane	N	N	N	N	NFI	NFI	46	34	34	41	26	I
1,2-Dichloropropane	N	N	N	N	NFI	NFI	57	61	44	62	23	I
Methyle ne chloride	N	9 B	11 B	3	67	I	7	7	4	6	43	14
Tetrachloroethylene	N	N	N	N	NFI	NFI	4	4	3	4	25	0
Trichloroethylene	N	N	N	N	NFI	NFI	5	4	3	4	40	0
1,1,1-Trichloroethane	N	N	N	N	NFI	NFI	110	60	81	98	26	I
1,1,2-Trichloroethane	4	N	N	6	100	I	N	N	N	N	NFI	NFI
Ethylbenzene	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Toluene	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
o-xylene	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Bis(2-ethylhexyl)phthalate	N	9	N	N	NFI	100	N	N	N	N	NFI	NFI
Butyl benzyl phthalate	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
1,4-Dichlorobenzene	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
2,4-Dimethylphenol	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
2,4-Dinitrophenol	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Naphthalene	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Nitrobenzene	7	N	N	N	100	NFI	N	N	N	N	NFI	NFI
4-Nitrophenol	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI
Phenol	N	N	N	N	NFI	NFI	N	N	N	N	NFI	NFI

D.: DUPLICATE
FILIN: INFLUENT TO FILTER, ug/L
FILOUT: EFFLUENT FROM FILTER, ug/L
% RED.: REDUCTION OF COMPOUND CAUSED BY THE FILTER *

B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NFI: COMPOUND NOT FOUND IN FILIN.

TABLE 6.23 (Continued)

COMPOUND	EVENT 5, DAY 70			EVENT 6, DAY 75					
	FILIN.	FILOUT.	% RED.	FILIN.	FILIN. D.	FILOUT.	FILOUT. D.	% RED.	% RED. D.
Acetone	3	6	I	28 B	40 B	55 B	16 B	I	60
Cyclohexanone	N	N	NFI	N	N	N	N	NFI	NFI
Furfural	N	N	NFI	N	N	N	N	NFI	NFI
Methy ethyl Ketone	N	N	NFI	N	570	2	N	I	ERR
Methyl isobutyl ketone	N	N	NFI	N	6	24	N	I	ERR
Tetrahydrofuran	160	420	I	N	N	100	N	I	NFI
Carbon tetrachloride	N	2	I	43	75	26	N	40	ERR
Chlorobenzene	N	N	NFI	130	240	17	N	87	ERR
Chloroform	14	23	I	59	100	43	14	27	86
1,2-Dichloroethane	42	76	I	150 B	280 B	74	47	51	83
1,2-Dichloropropane	19	35	I	11	14	41	21	I	I
Methylene chloride	140	130	7	7	240	230 B	68 B	I	72
Tetrachloroethylene	N	7	NFI, I	9	14	24	3	I	79
Trichloroethylene	2	3	I	130	N	24	N	82	NFI
1,1,1-Trichloroethane	N	3		N	N	29	N	I	NFI
1,1,2-Trichloroethane	43	87	I	5 B	4 B	70	55	I	I
Ethylbenzene	N	N	NFI	N	N	16	N	I	NFI
Toluene	N	N	NFI	N	5	27 B	4 B	I	20
o-xylene	N	N	NFI	N	N	17	N	I	NFI
Bis(2-ethylhexyl)phthalate	N	N	NFI	N	N	N	N	NFI	NFI
Butyl benzyl phthalate	N	N	NFI	N	N	N	N	NFI	NFI
1,4-Dichlorobenzene	N	N	NFI	N	N	N	N	NFI	NFI
2,4-Dimethylphenol	N	N	NFI	N	N	N	N	NFI	NFI
2,4-Dinitrophenol	N	N	NFI	N	N	N	N	NFI	NFI
Naphthalene	N	N	NFI	N	N	N	N	NFI	NFI
Nitrobenzene	N	N	NFI	N	N	N	N	NFI	NFI
4-Nitrophenol	N	N	NFI	N	N	N	N	NFI	NFI
Phenol	N	N	NFI	N	N	N	N	NFI	NFI

D.: DUPLICATE
FILIN: INFLUENT TO FILTER, ug/L
FILOUT: EFFLUENT FROM FILTER, ug/L
% RED.: REDUCTION OF COMPOUND CAUSED BY THE FILTER

B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NFI: COMPOUND NOT FOUND IN FILIN.

TABLE 6.23 (Continued)

COMPOUND	EVENT 7, DAY 78			EVENT 8, DAY 82		
	FILIN.	FILOUT.	% RED.	FILIN.	FILOUT.	% RED.
Acetone	29	45	I	19	110	I
Cyclohexanone	N	N	NFI	N	N	NFI
Furfural	N	N	NFI	N	N	NFI
Methy ethyl Ketone	N	N	NFI	N	N	NFI
Methyl isobutyl ketone	N	N	NFI	N	N	NFI
Tetrahydrofuran	170	220	I	230	220	4
Carbon tetrachloride	N	3	NFI, I	4	N	100
Chlorobenzene	N	N	NFI	N	N	NFI
Chloroform	22	33	I	39	38	3
1,2-Dichloroethane	69	99	I	120	110	8
1,2-Dichloropropane	27	43	I	50	49	2
Methylene chloride	180	140	22	65	62	5
Tetrachloroethylene	2	8	I	10	9	10
Trichloroethylene	2	5	I	8	7	13
1,1,1-Trichloroethane	3	6	I	7	7	0
1,1,2-Trichloroethane	65	110	I	120	110	8
Ethylbenzene	N	N	NFI	N	N	NFI
Toluene	N	N	NFI	N	N	NFI
o-xylene	N	N	NFI	N	N	NFI
Bis(2-ethylhexyl)phthalate	N	N	NFI	N	N	NFI
Butyl benzyl phthalate	N	N	NFI	N	N	NFI
1,4-Dichlorobenzene	N	N	NFI	N	N	NFI
2,4-Dimethylphenol	N	N	NFI	N	N	NFI
2,4-Dinitrophenol	N	N	NFI	N	N	NFI
Naphthalene	N	N	NFI	N	N	NFI
Nitrobenzene	N	N	NFI	N	N	NFI
4-Nitrophenol	N	N	NFI	N	N	NFI
Phenol	N	N	NFI	N	N	NFI

FILIN: INFLUENT TO FILTER, ug/L
FILOUT: EFFLUENT FROM FILTER, ug/L
% RED.: REDUCTION OF COMPOUND CAUSED BY THE FILTER

I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NFI: COMPOUND NOT FOUND IN FILIN.

TABLE 6.23 (Continued)

COMPOUND	EVENT 9, DAY 84						EVENT 10, DAY 88		
	FILIN.	FILIN. D.	FILOUT.	FILOUT. D.	% RED.	% RED. D.	FILIN.	FILOUT.	% RED.
Acetone	38	42 B	N	N	ERR	ERR	19	22	I
Cyclohexanone	N	N	N	N	NFI	NFI	N	N	NFI
Furfural	N	N	N	N	NFI	NFI	N	N	NFI
Methy ethyl Ketone	N	N	N	N	NFI	NFI	N	9	I
Methyl isobutyl ketone	N	N	N	N	NFI	NFI	14	N	ERR
Tetrahydrofuran	240	220	130	140	46	36	190	60	68
Carbon tetrachloride	4	4	3	2	25	50	3	3	0
Chlorobenzene	N	N	N	N	NFI	NFI	N	N	NFI
Chloroform	30	31	27	25	10	19	35	32	9
1,2-Dichloroethane	99	100	86	84	13	16	110	120	I
1,2-Dichloropropane	41	43	42	41	I	5	48	54	I
Methylene chloride	62	64 B	60 B	60 B	3	6	50	65	I
Tetrachloroethylene	8	9	7	6	13	33	8	8	0
Trichloroethylene	6	6	6	5	0	17	5	5	0
1,1,1-Trichloroethane	5	6	4	4	20	33	6	7	I
1,1,2-Trichloroethane	100	110	100	100	0	9	100	120	I
Ethylbenzene	N	N	N	N	NFI	NFI	N	N	NFI
Toluene	N	N	N	N	NFI	NFI	N	N	NFI
o-xylene	N	N	N	N	NFI	NFI	2	2	0
Bis(2-ethylhexyl)phthalate	N	N	N	14	NFI	I	6 B	N	100
Butyl benzyl phthalate	N	N	N	N	NFI	NFI	N	N	NFI
1,4-Dichlorobenzene	N	N	N	N	NFI	NFI	N	N	NFI
2,4-Dimethylphenol	N	N	N	N	NFI	NFI	N	N	NFI
2,4-Dinitrophenol	N	N	N	N	NFI	NFI	N	N	NFI
Naphthalene	N	N	N	N	NFI	NFI	N	N	NFI
Nitrobenzene	N	N	N	N	NFI	NFI	N	N	NFI
4-Nitrophenol	N	N	N	N	NFI	NFI	N	N	NFI
Phenol	5	6	N	N	100	100	N	N	NFI

D.: DUPLICATE
FILIN: INFLUENT TO FILTER, ug/L
FILOUT: EFFLUENT FROM FILTER, ug/L
% RED.: REDUCTION OF COMPOUND CAUSED BY THE FILTER

B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NFI: COMPOUND NOT FOUND IN FILIN.

TABLE 6.23 (Continued)

COMPOUND	EVENT 11, DAY 89		
	FILIN.	FILOUT.	% RED.
Acetone	N	22	I
Cyclohexanone	N	N	NFI
Furfural	N	N	NFI
Methy ethyl Ketone	N	9	I
Methyl isobutyl ketone	N	N	NFI
Tetrahydrofuran	230	60	74
Carbon tetrachloride	3	3	0
Chlorobenzene	N	N	NFI
Chloroform	28	32	I
1,2-Dichloroethane	120	120	0
1,2-Dichloropropane	46	54	I
Methylene chloride	93 B	65	22
Tetrachloroethylene	8	8	0
Trichloroethylene	5	5	0
1,1,1-Trichloroethane	N	7	I
1,1,2-Trichloroethane	110	120	I
Ethylbenzene	N	N	NFI
Toluene	N	N	NFI
o-xylene	2	2	0
Bis(2-ethylhexyl)phthalate	N	N	NFI
Butyl benzyl phthalate	N	N	NFI
1,4-Dichlorobenzene	N	N	NFI
2,4-Dimethylphenol	N	N	NFI
2,4-Dinitrophenol	N	N	NFI
Naphthalene	N	N	NFI
Nitrobenzene	N	N	NFI
4-Nitrophenol	N	N	NFI
Phenol	6	N	100

D.: DUPLICATE
FILIN: INFLUENT TO FILTER, ug/L
FILOUT: EFFLUENT FROM FILTER, ug/L
% RED.: REDUCTION OF COMPOUND CAUSED BY THE FILTER

B: COMPOUND FOUND IN BLANK
I: INFLUENT CONCENTRATION LESS THAN EFFLUENT CONCENTRATION
N: NONE DETECTED
NFI: COMPOUND NOT FOUND IN FILIN.

TABLE 6.24, SUMMARY OF TOXIC FILTER SAMPLING EVENTS

ACCLIMATED CONDITIONS

COMPOUND	EVENT 4		EVENT 9	
	FILIN.	% RED.	FILIN.	% RED.
Acetone			40	100
Tetrahydrofuran			230	41
Chloroform	30	21	31	15
1,2-Dichloroethane	88	9	100	15
1,2-Dichloropropane	40	6	42	1
Methylene chloride	59	10	63	5
Tetrachloroethylene			9	24
Trichloroethylene	4	13	6	8
1,1,1-Trichloroethane			6	3
1,1,2-Trichloroethane			105	5
Phenol			6	100

FILIN.: INFLUENT TO FILTER
% RED.: PERCENT REDUCTION OF COMPOUND BY FILTER

filter. However, values for these compounds were only found in Event 9. The remaining compounds, for both Events 4 and 9 had removals under 20%. A low removal efficiency would be expected as the filters were designed to physically remove solids, and only the RCRA compounds adsorbed to the suspended solids would be expected to be removed.

6.6 QUALITY CONTROL

To insure representative and comparative results for this study, standard and proven methods were utilized for sample collection and analysis. All control variables (flows, D.O., pH, alkalinity, etc.) were measured by base operators at the USEPA Test & Evaluation Facility in accordance with the "Quality Assurance Program Plan Base level of Support, USEPA Test & Evaluation Facility," EPA Contract No. 68-03-4038. Provisions in the plan include procedures for sample collection, compositing and preservation, instructions for analysis and a QA/QC program. In addition, the laboratory also participates in the USEPA Water Pollution Laboratory Performance Evaluation Study every 6 months. The process parameters (nitrogen series, COD etc.) were measured by the USEPA Toxics Research & Analytical Support Staff. This laboratory also has a QA/QC plan that includes lab standards, duplicate sample analyses and participation in the Water Pollution Laboratory Performance Evaluation Study every 6 months. The toxics analyses were considered to have a level 3 quality objective. The analyses were performed by PEI Analytical Services in accordance with EPA approved methods and specifications under contract with the EPA (contract No. 68-03-3389).

This study was conceived to measure toxics removal from sidestreams of spiked primary effluent or secondary effluent diverted from the conventional activated sludge system used in Work Assignment No. 0-W04.0. Sampling frequency, analytical procedures and quality assurance objectives are listed in the quality assurance plan for that project titled "RCRA Pilot-Scale Study of Toxics Removal." The precision requirement for the control variables and process parameters were specified as percent relative range, with an upper limit of 15%. However to conform to precision calculations in quality assurance plans for current projects, the percent deviation about the mean was utilized for this study. Percent deviation about the mean = $|X_1 - X_2|/(X_1 + X_2) * 100$

Where:

X_1: sample value
X_2: duplicate value

The upper limit selected was 15% to correspond with the percent relative range specification. Table 5.25 shows the percent deviation about the mean (average precision) and percent

duplication for the variables COD, ammonia, nitrate, TKN, TP, TSS and VSS for the entire project. The value for each particular type of analysis was obtained by averaging the percent deviation about the mean for each sample with a duplicate. For all of the analyses except ammonia, the values were below the 15% criteria. The standard deviation listed in Table 6.25 is for all of the percent deviation about the means that made up the average precision value. Completeness was defined as the number of usable data points divided by the number collected for each particular analysis, and was set at a minimum of 95%. Completeness was recorded directly within the data tables in this section, and are overall within the 95% completeness specification. Duplicate samples were also collected for toxics analysis and are reported in the data tables of this section.

Standard deviation was utilized to assess the similarity of the results within each particular phase of the project. Standard deviation was calculated as follows:

$$S.D. = \text{square root}(\text{sum}(x_i - AVG)^2/n)$$

where

AVG = average of all n values
n = total number of values
S.D. = standard deviation
X_i = the ith item in the list

Because of the variability of the wastewater these standard deviation values, reported within the data tables, are not indications of the quality of the analysis but rather were used to assess the operating conditions of the system for each test period.

TABLE 6.25, QUALITY CONTROL

PARAMETER	AVERAGE PRECISION	NUMBER OF DUPLICATE SAMPLES	STANDARD DEVIATION	PERCENT DUPLICATION
COD*	6.7	14	7.9	13
AMMONIA*	17.4	17	17.9	10
NITRATE*	9.4	15	13.5	10
TKN*	5.7	17	5.3	10
TP*	5.8	17	5.6	13
TSS**	14.7	79	19.9	11
VSS**	8.7	15	14.9	11

*: AVERAGE PRECISION FOR AERATION BASIN INFLUENT, SECONDARY EFFLUENT AND MIXED LIQUOR

**: FOR SAMPLES LISTED ABOVE AND RECYCLED SLUDGE

SECTION 7
REFERENCES

1. Alleman, James E. and Irvine, Robert L., "Storage Induced Denitrification using Sequencing Batch Reactors," Water Research, Vol. 14, pp. 1483-1488, 1980.

2. American Chemical Society, RCRA and Laboratories, Washington, DC, 1986.

3. Andrews, William A., Environmental Pollution, Prentice-Hall, Inc., 1972.

4. APHA-AWWA-WPCF, Standard Methods for the Examination of Water and Wastewater, 16th ed., 1985.

5. Bowers, A. R., Eckenfelder, W. W., Gaddinpati, P. and Monsom, R. M., "Toxicity Reduction in Industrial Wastewater Discharges," Pollution Engineering, pp. 68-72, ebruary, 1988.

6. Brown and Caldwell, Process Design Manual for Nitrogen Control, U.S. Environmental Protection Agency Technology Transfer, PB-259149, 1975.

7. Cheremisinoff, Paul M., "Biotechnology: Treating Industrial/Municipal Wastes and Wastewater," Pollution Engineering, Volume XIX, Number 9, pp. 74-87, Sept., 1987.

8. Chiou, Cary T., Freed, Virgil H., Schmedding, David W. and Kohnert, Rodger L., "Partition Coefficient and Bioaccmulation of Selected Organic Chemicals," Environmental Science & Technology, Volume II, Number 5, pp. 475-478, May, 1977.

9. CMA (Chemical Manufacturers Association), "Chemical Industry Watches its Waste," ChemEcology, p. 2, June, 1987.

10. Federal Register, 40 CFR Part 13C, Part VIII, October 26, 1984.

11. Hammer, Mark J., Water And Waste-Water Technology, John Wiley and Son, New York, 1975.

12 Hannah, Sidney A., Austern, Barry M., Eralp, Atal E. and Wise, Robert H., "Comparative Removal of Toxic Pollutants by Six Wastewater Treatment Processes," Journal WPCF, Volume 58, pp. 27-34, January, 1986.

13. Hill, N. P., McIntyre, Perry R., and Lester, J. N., "Behavior Of Chlorophenoxyl Herbicides During The Activated

Sludge Treatment Of Municipal Waste Water," Wat. Res., Vol, 20, No. 1, pp 45-52, 1986.

14. Kincannon, F. M., Stover, Enos C., Nichols, Virgil and Meldley, David, "Removal Mechanisms for Toxic Priority Pollutants," Process Research, pp. 157-163, Volume 55, Number 2, February, 1983.

15. King, E. F., Painter, H. A., "The Effect of Acclimation on the Toxicity of Chemicals to Activated Sludge Microorganisms," Environ. Pollut. Ser. A, Volume 39, pp. 267-280, 1985.

16. Kobayashi, Hester and Ritmann, Bruce E., "Microbia Removal of Hazardous Organic Compounds," Environmental Science Technology, Volume 16, Number 3, pp. 170A-183A, 1982.

17. Lambert, Martha, Assuring Data Quality in the Environmental Laboratory, Cincinnati, Ohio: University of Cincinnati: 1983, 70 p. Master's Thesis.

18. Lue-Hing, Cecil, Washington, Booker, Zenz, David C., Obayshi, Alan W. and Prakasam, T. B., Full-Scale Combined Carbon Oxidation--Nitrification At The Metropolitan Sanitary District of Greater Chicago, Metropolitan Sanitary District of Chicago, Chicago, ILL.

19. Maxwell, Mark J., Linstedt, K. D., Work, S. W. and Bennett, E. R., "Making Optimum use of Filter Media in Wastewater Filtration," Water & Sewage Works, pp. 56-61, December, 1977.

20. McGregor, Geroge I., Overview of Environmental Law, A guidebook for Professionals, McGregor Shea & Doliner, P.C., Boston, 1985.

21. Melcer, H. and Bedford, W. K., "Removal of Pentachlorophenol in Municipal Activated Sludge Systems," Journal WPCF, Volume 60, Number 5, pp. 622-635, May, 1988.

22. Metcalf & Eddy, Inc., Wastewater Engineering Treatment/Disposal/Reuse, 2nd ed., McGraw-Hill Book Co., New York, 1979.

23. Monk, Robert C., "Design Options for Water Filtration," Journal AWWA, pp. 93-106, September, 1987.

24. Namkung, Eun and Rittmann, Bruce, E., "Estimating Volatile Organic Compound Emissions from Publicly Owned Treatment Works," Journal WPCF, Vol. 59, No. 7, pp. 670-678, July, 1987.

25. Newton, Jim, "OCPSF Effluent Limits Pretreatment, and NSPS," Pollution Engineering, pp. 48-51, March, 1980.

26. PEI ASSOCIATES, Inc., "Collection and Analysis of Offgas Samples and Analysis of Liquid and Sludge Samples from RCRA Pilot Project," Contract No. 68-03-3389, July, 1988.

27. Petrasek, Albert C., Austern, Barry M. and Neiheisel, Timothy W., "Removal And Partitioning Of Volatile Organic Priority Pollutants In Wastewater Treatment," Ninth U.S. Japan Conference on Sewage Treatment Technology, Tokyo, Japan, Sept., 1983.

28. Petrasek, Albert C., Kugelman, Irwin, J., Austern, Barry M., Pressley, Thomas A., Winslow, Lawrence A. and Wise Robert H., "Fate of Toxic Organic Compounds in Wastewater Treatment Plants," Journal WPCF, Volume 55, pp. 1286-1296, October 1983.

29. Quarles, John, Federal Regulation of Hazardous Wastes A Guide to RCRA, The Environmental Law Institution, Washington DC, 1982.

30. Sherrard, Joseph H., Scearce, Steven N., Benninger, Robert W. and Weber, A. Scott, "Influence of the COD: TKN: NH_4^+-N Ratio on Nitrification and Alkalinity in the Activated Sludge Process," J. Civil Eng. Design, 2(1), pp. 31-44, 1984.

31. Smith, A. G., "Nitrification in Activated Sludge Plants. Guidelines on some Operation and Design Aspects," Research Publication W62, Ministry of the Environment, Ontario, Canada, 1977.

32. Stenstrom, Michael K. and Poduska, Richard A., "The Effect of Dissolved Oxygen Concentration On Nitrification," Water Research, Vol. 14, pp. 643-649, 1980.

33. Stover, Enos L. and Kincannon, Don F., "Biological Treatability of Specific Organic Compounds found in Chemical Industry Wastewaters," 36th Purdue Industrial Waste Conference, May 1981.

34. Tabak, Henry H., Quave, Stephen A., Mashni, Charles I. and Barth, Edwin F., "Biodegradability Studies with Organic Priority Pollutant Compound," Journal WPCF, Volume 53, Number 10, pp. 1503-1518, October, 1981.

35. Tabak, Henry H., Wastewater Research Division, Highlight Memo, U.S. EPA, Cincinnati, Ohio, 1988.

36. Thibodeaux, Louis J., Chemodynamics. Environmental Movement of Chemicals in Air, Water and Soil, John Wiley and Son, New York, 1979.

37. U.S. Department of Health and Human Services, NIOSH Pocket Guide to Chemical Hazards, Washington DC., 1985.

38. U.S. EPA, Methods for Chemical Analysis of Water and Wastes, EPA 600 14-79-020 Cincinnati, Ohio, 1979.

39. U.S. EPA, "Report to Congress on the Discharge of Hazardous Waste to Publicly Owned Treatment Works," EPA/530-SW-86-004, Washington DC., 1986.

40. U.S. EPA, "The Resource Conservation And Recovery Act," Public Law 94-580 94th Congress, October 21, 1976.

41. U.S. EPA T & E Facility, "Quality Project Plan," Contract #68.034038, Cincinnati, Ohio, 1987.

42. U.S. EPA Technology Transfer Seminar Publication, "Nitrification and Denitrification Facilities," 1973.

43. Verschuereh, Karel, Handbook of Environmental Data on Organic Chemicals , Van Nostrand Reinhold and Company, New York, 1983.

44. Wang, Lawrence K., Wang, MuHao, Poon, Calvin P. C. and Bergenthal, Jon, "Chemistry of Nitrification-Denitrification Process," The Journal of Environmental Sciences, pp. 23-28, November/December, 1978.

45. WPCF, Wastewater Treatment Plant Design, WPCF Manual of Practice No. 8, ASCE Manual on Engineering Practice No. 36, Lancaster Press, Inc., Lancaster, PA., 1982.

46. Young, James C., "Operating Problems with Wastewater Filters," Journal WPCF, Volume 57, Number 1, pp. 22-29, January, 1985.